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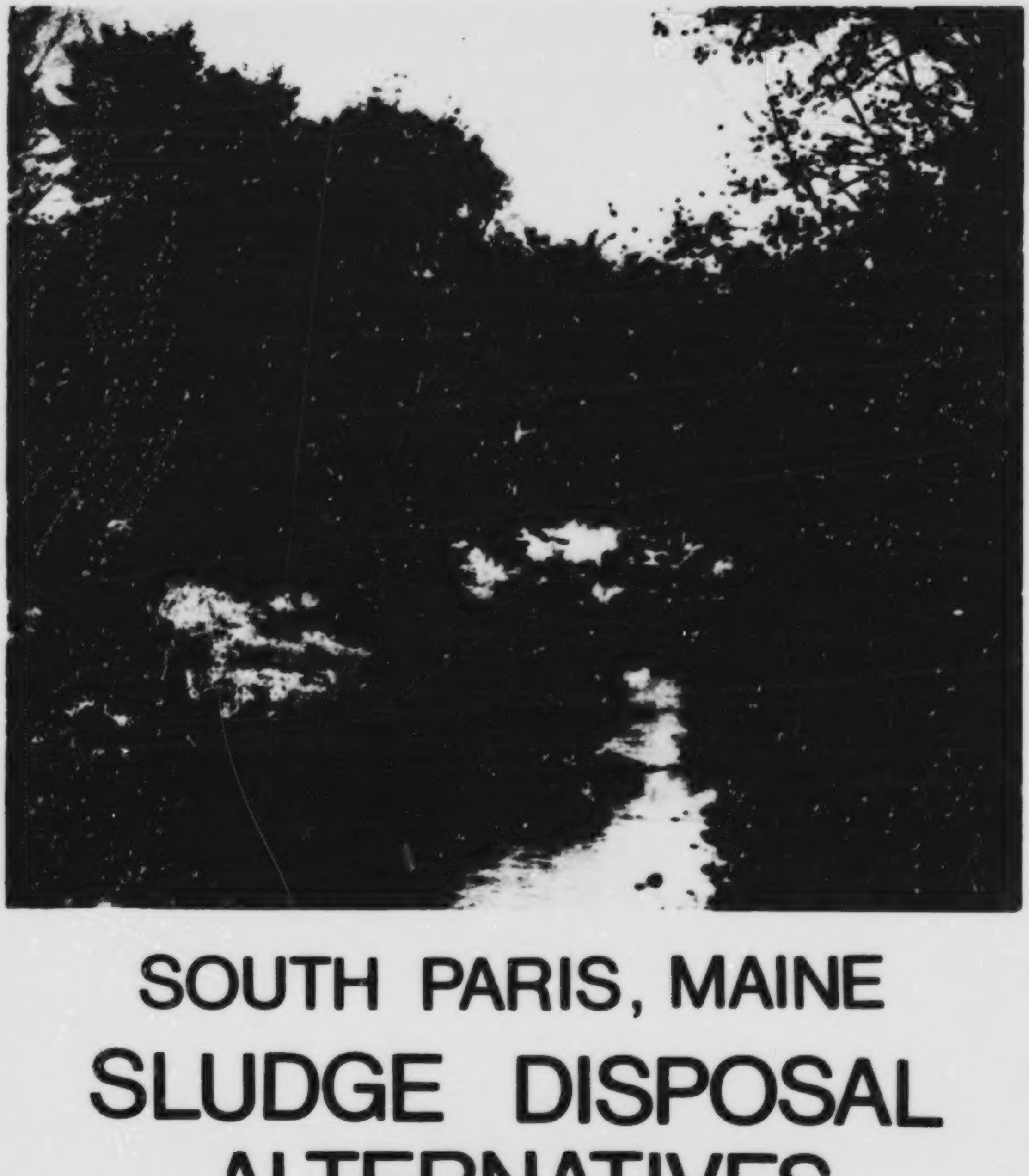

SOUTH PARIS, MAINE

SLUDGE DISPOSAL ALTERNATIVES

U.S. Environmental Protection Agency
New England Regional Office, Boston, Mass.

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DRAFT ENVIRONMENTAL IMPACT STATEMENT
ON
ANALYSIS OF SLUDGE DISPOSAL ALTERNATIVES FOR SOUTH PARIS, MAINE

Prepared for the

U.S. ENVIRONMENTAL PROTECTION AGENCY
Region I Office
Boston, Massachusetts

by

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I. INTRODUCTION

A. Background

In 1973, the U.S. Environmental Protection Agency undertook to construct a secondary wastewater treatment facility with the Paris (Maine) Utility District. The facility, intended primarily to alleviate water quality problems caused by effluent from the A. C. Lawrence Tannery, began operation in June, 1975.

EPA's original environmental review of the treatment facility plans concluded that the project would have net beneficial effects and a negative declaration of environmental impacts was prepared. Subsequently, however, the Maine Board of Environmental Protection refused the Utility District permission to dispose dewatered sludge from the treatment facility at the intended (and previously used) site. Construction of the treatment plant itself was approved and temporary permission granted to continue sludge disposal at the original landfill while a new site was located.

The Paris Utility District initiated a study of alternative landfill sites. A total of six locations were reviewed, including the original site, although only three received detailed study. Based on this evaluation the Utility District applied to the Board of Environmental Protection for permission to dispose the sludge on a 52-acre tract in the Ryerson Hill area, some eight miles from the treatment facility. Plans were submitted for permanently lowering the perched groundwater table on this site (currently at a depth of one to three feet) to ensure that an adequate layer of dry soil would underlie the sludge and prevent leaching of pollutants into the groundwater.

The Board of Environmental Protection held five days of public hearings on the application during the summer and fall of 1975. Some 1,200 pages of testimony were taken. The principal controversial issues as cited by the board in its findings were:

- effectiveness and impact of lowering the groundwater table;
- leaching of pollutants from the sludge and their entry into groundwater or surface waters; and
- traffic problems caused by sludge haul trucks and the ability of the trucks to continue operations year-round.

Following the hearings, the board approved the application subject to several requirements, including a detailed erosion control plan, proof that the proposed drainage system would lower the groundwater table at the site, and a detailed monitoring program to insure that water quality standards would be met.

The Board of Environmental Protection is limited by Maine statutes to evaluation of the single site submitted by the applicant. EPA's original environmental assessment and negative declaration had not considered sludge disposal at the Ryerson Hill site. Several local citizens requested an Environmental Impact Statement fully investigating sludge disposal alternatives. The Board of Environmental Protection concurred that an EIS would be helpful, and urged that the study be conducted immediately in view of the long delays already experienced in choosing a disposal site and method.

These events, and the actions and decisions of the participants, were predicated on a relatively small quantity of empirical data. Although raw wastewater from the tannery, effluent quantity, and sludge composition were analyzed in a pilot plant study, these analyses were limited in scope and were not repeated for the full scale plant in daily operation. Investigations of landfill site alternatives produced limited data on soil composition and groundwater quality, while alternative disposal methods were not considered. The resulting lack of information increased uncertainty among local residents, whose participation in the planning process was limited. EPA therefore initiated a detailed, independent analysis with the intent of issuing an Environmental Impact Statement on sludge disposal alternatives for the South Paris treatment facility. An initial public workshop was held on July 9, 1976, to discuss the objectives and scope of the study. In August, EPA contracted with EIC Corporation of Newton, Massachusetts, to perform the necessary analyses.

B. Study Scope and Objectives

The principal objective of the study was to identify the optimum method of sludge disposal for South Paris, that is, the most cost-effective alternative with acceptable environmental impacts. Given the special circumstances enumerated above, the Draft Environmental Impact Statement focused on sludge disposal rather than on a more comprehensive assessment of wastewater treatment as it may affect disposal alternatives. The unusual nature of the sludge, its presence in large quantities at a historical dump site, and the need for minimum delay in developing recommendations dictated this choice.

A second objective of special importance in this study was to actively involve local citizens in the process of assessing sludge disposal alternatives. Previous public hearings had produced considerable controversy and polarization of opinions regarding this issue. Therefore, a goal of the study was to seek a consensus through public presentation of interim results and solicitation of public opinions and recommendations.

Finally, the environmental impacts of the existing tannery sludge deposits were analyzed in detail in the course of this project. The presently used site contains many years of sludge deposits; their impacts had to be established and any adverse effect on groundwater quality assessed. Analysis of these impacts provided essential information on leachate generation and pollutant mobility for the sludge in question.

C. Characterization of the Sludge Disposal Problem

Sludge generated by the South Paris wastewater treatment facility is unusual because of the character of the influent to the facility. Currently, some 90 percent of the raw wastewater originates at the A. C. Lawrence Company's topside leather tannery in South Paris, with the remaining 10 percent representing ordinary sanitary sewage and cannery effluent. As a result, the waste stream entering the treatment facility has a high solids content and high concentrations of chromium and other constituents used in the tanning process.

The treatment facility combines primary sedimentation with a carbonation step and secondary biological treatment. Separate sludges are generated from each of the three treatment steps; primary and carbonation sludges are combined and centrifuged and the resulting dewatered solids are carried by conveyor belt to storage and transport containers where they are combined with centrifuged waste activated sludge.

The facility was designed to treat a chemically complex influent with essentailly conventional processes. It has experienced intermittent operational problems since the tannery effluent was brought on-line in September of 1975. The origin of these problems is not fully understood. One result, however, has been bulking of the plant. As a consequence, secondary (waste-activated) sludge was not being produced during the study period. The primary and carbonation sludge currently has a dry solids content of only about 14 percent; design levels were 30 to 35 percent for primary sludge and 22 percent for combined, final sludge.

The general elements of the sludge disposal problem, therefore, may be summarized as follows:

- the sludge has a complex chemical composition
- the ultimate composition and volume of sludge to be disposed are currently uncertain.

The complexities and uncertainties make the choice and evaluation of disposal alternatives unusually difficult, since criteria and conclusions applicable to typical sludges are unsuitable in this case. They may also help explain in part the controversy surrounding disposal of sludge and the divergent opinions about probable environmental impacts. To settle these questions, extended field data collection and analysis were carried out to ensure that findings and conclusions were situation-specific.

D. Contents of the EIS

Section II gives a brief description of the environmental setting, focusing on the physical, socioeconomic, and institutional features of the South Paris area relevant to the sludge disposal problem. Section III presents disposal alternatives and describes in some detail viable options. Section IV analyzes land disposal at the A. C. Lawrence and Ryerson Hill sites. Section V summarizes findings of the study.

Analytical procedures and other technical material are presented in the Appendices which should be consulted for information supporting the conclusions and recommendations presented in the main text.

II. THE ENVIRONMENTAL SETTING

A. General Background

The Town of Paris comprises some 65 square miles in Oxford County, Maine. In 1975, the town had a population of some 4,300, a 10 percent increase since 1970. Manufacturing supplies about half the available jobs and is the principal economic base of the town and county.

Paris contains two major core areas. The earliest settlements were in the area now known as Paris Hill, which served as the town center. Establishment of railroad service in the mid-nineteenth century, however, caused a transfer of commercial and industrial activity to the southern portion of the town (present South Paris) where the rails were laid. Since 1900, South Paris has been the town's center of commercial activity, while Paris Hill has remained predominantly residential. Recent residential development has centered in the area between South Paris and Paris Hill.

South Paris and the adjacent Norway Village form the second largest commercial-industrial center in Oxford County. The land along Routes 26 and 117, as well as the Canadian National Railroad spurs, contains intensive industrial development.

Paris lies in the foothills of the Appalachian Mountains and its topography reflects glacial origins. A series of hills rise on both sides of the Little Androscoggin River Valley, reaching heights more than 600 feet above the valley floor. The valley itself is underlain by glacial sand and gravel deposits representing a significant aquifer. Drainage from the surrounding hills recharges the Little Androscoggin River and the underlying aquifer, as well as many brooks and streams that flow through nearby communities.

B. Local Geology and Hydrology

Approximately fourteen thousand years ago a large mass of continental glacial ice began to disintegrate over the northeastern United States. In the area of the Little Androscoggin River Valley, the advancing ice apparently removed very little material, but it did deposit a discontinuous layer of glacial till over the bedrock hills of the area. As the ice melted down and exposed the topographically high bedrock and till areas, meltwater streams deposited sand and gravel along the ice margin and in tunnels beneath the ice. These stream deposits later became kame terraces and eskers. Closely following the dissipation of the glacial ice, the area of the Androscoggin and Little Androscoggin River Valleys was subjected to a marine submergence. Glaciomarine silt and sand were deposited to a present elevation of approximately 400 feet in the Androscoggin River Valley, and at least 350 feet in the Little Androscoggin River Valley.

During the period of marine deposition, and immediately afterwards, glaciofluvial sands were transported and deposited down-valley by glacial melt water streams. These outwash sands have thicknesses well in excess of one hundred feet. As the marine waters receded to present sea level, the outwash sands were incised as streams readjusted to a lowered regional base level.

The till deposits are typically low in permeability and are, accordingly, poor aquifers. The ice contact deposits are the most significant aquifers in the Lower Androscoggin Basin. Depending on local circumstances, yields of wells may be quite high (up to 2000 gpm). The outwash deposits also have appreciable permeability with yields up to 100 gpm — some artificial gravel packed wells in outwash reach 600-700 gpm or more.

The marine sediments are quite impermeable and play an important role in the regional hydrology, since they often stratigraphically bound the highly permeable ice contact and outwash deposits and thereby influence discharge and recharge patterns.

The glacial geology of the region creates a somewhat unusual hydrologic pattern. In upland areas, particularly on tops and sides of bedrock hills, perched water tables often occur within a few feet of the soil surface. Flows are confined to the uppermost levels of the glacial till, where weathering has created permeable conditions. At greater depths, the till retains its glacially compacted, impermeable structure. The hillsides of South Paris, therefore, frequently exhibit poorly drained, marsh-like conditions.

In contrast, the lowlands of the area are characteristically well drained, with groundwater occurring at greater depths, if at all. Here, the initial till deposits have been covered by glaciofluvial sands and gravel through which water flows readily. However, marine sediment strata, as well as localized outcrops of till and bedrock, may create highly complex flow patterns and isolate areas with no permanent water table.

The groundwater of the region eventually enters a major aquifer underlying the Little Androscoggin River. The aquifer appears to occur throughout the length of the Little Androscoggin River Basin, but varies significantly in depth and width. It is tapped for public water supply by Paris and by the towns of Norway and Oxford downstream. The aquifer is the only significant source of potable water for the region.

C. Water Quality and Supply

The growth of the town of Paris has created some surface water quality problems. Industrial activities in South Paris generate some 1.15 million gallons per day (mgd) of wastewaters. Until 1975, these wastes were discharged into the river with minimal treatment. As a result, the 6.3 mile segment of the Little Androscoggin River from South Paris to Oxford was the most severely polluted surface water in the Androscoggin Basin. Above South Paris, the Little Androscoggin is of substantially higher quality.

Groundwater in the region is generally free of significant contamination. In particular, the aquifer underlying the river yields high quality water. However, incidents of high chloride content -- probably attributable to deicing salts applied to highways -- have been reported with increasing frequency in recent years.

Wells supply all the water consumed in Paris. Most residences rely on private wells for water supply. Municipal wells provide some 500 million gallons of water per year to more than 1,000 domestic and industrial users. The majority of public water production -- about 300 million gallons per year -- is used by the A. C. Lawrence tannery.

The water supply and sewage facilities are owned and operated by the Paris Utility District (PUD), a quasimunicipal institution created by legislative action in 1967. The district is administered by a five-person board of trustees, whose members are elected at the annual town meeting.

South Paris has a sewer system dating back to the early 1900's which serves the majority of the village. In conjunction with construction of the treatment facility, sewers were extended to serve part of Paris Hill. The PUD plans to continue such extensions over the next few years.

The secondary treatment plant in South Paris is a central element in water quality management for the area. Prior to its construction the town discharged untreated and partially treated sanitary wastes through three outfalls to the Little Androscoggin River, while partially treated industrial wastes were discharged to the river by the A. C. Lawrence tannery and the A. L. Stewart cannery. These flows, amounting on average to 0.2, 1.0 and 0.15 million gallons per day (mgd), respectively, are now treated at the South Paris facility, along with stormwater from the older combined sewer system. The Maine Department of Environmental Protection has specified a "D" classification for the Little Androscoggin below South Paris. This classification implies suitability only for power generation, navigation, and industrial process water requirements. Their computer projections, however, indicate that the river cannot assimilate even the treated effluent from the South Paris wastewater facility and that this river segment will fall short of Class D requirements in the foreseeable future.

Water supply plans for the region center on the major aquifer underlying the river. Flow volumes through the aquifer vastly exceed current withdrawals and could support all forecasted growth.

D. Biological Resources

The principal location of major biological resources in the Paris region is the upland areas. Characterized by mixed deciduous and coniferous forests, bogs, and wooded swamps, the uplands offer a variety of conditions for vegetative growth and a diversity of habitat for wildlife. Most key species of the region — the white-tailed deer, ruffed grouse, fisher, woodcock, and pheasant — are considered primarily upland dwellers, although they may spend time feeding or ranging in lowland areas.

The white-tailed deer is perhaps the most popular game species of the region. The neighboring towns of Paris, Oxford, and Norway are estimated to contain some 18 percent of the state's deer habitat. In heavy winters, deer band together in areas called deer yards. Paris contains four recognized potential deer yards in upland areas near Paris and Ryerson Hill.

The region also contains abundant fresh water fisheries. The most popular game species are land-locked salmon, brook trout, and lake trout. In Paris, there are no salmon fisheries, and only Hall Pond contains a significant brook trout population (due largely to stocking). The northern uplands of the town, however, contain the headwaters of several brooks that reportedly become trout fisheries further downstream.

Waterfowl represent the major wildlife species relying on lowlands for their habitat. On migrating flights, they tend to follow major waterways, of which the Androscoggin and its tributaries are a good example.

There are no known rare or endangered species of plants or animals in the town of Paris.

E. Socioeconomic Features

The economic and demographic character of Paris is typical of many towns in southern Maine. Both the town and the region depend heavily on manufacturing and trade as key elements on their economic base. In Oxford County, for example, manufacturing provides nearly half of all jobs, as compared with some 25 percent for the U.S. as a whole.

In Paris, this reliance centers on a few manufacturing firms, including the A. C. Lawrence tannery, which supply a significant percentage of job opportunities in the town. Accordingly, there is public commitment to cooperate in maintaining the industrial base, as reflected in municipal treatment of tannery and cannery wastes under a cost-sharing agreement.

Virtually all the residences in Paris are single-family homes, although there is substantial variation in the intensity of land use. The relatively dense development in South Paris gives way to larger lots and open areas near Paris Hill, with scattered farms and largely undeveloped land occurring elsewhere in the town.

Paris Hill is also a significant cultural resource. Originally settled in about 1780, the village grew to some 300 or 400 residents in the next 15 years. It continued as a thriving community until 1895, when the county seat moved to South Paris. Since then little new development has occurred, while many historical buildings have been preserved.

Most of the present buildings were constructed between 1800 and 1860. They are of high architectural quality, the majority representing Federal and Greek revival designs. Both the village as a whole and some 47 individual structures are listed in the National Register of Historic Places compiled by the National Park Service.

F. Environmentally Sensitive Areas

The principal environmentally sensitive areas in Paris are:

- the Little Androscoggin River below South Paris
- the regional aquifer underlying the Little Androscoggin River
- the complex of small streams and brooks forming in the uplands of the town; and
- the historic development at Paris Hill.

The segment of the Little Androscoggin below South Paris is significant because it is a focal point of water quality improvement for the region. Any further degradation would reduce the probability that this segment will achieve its assigned classification.

The regional aquifer is the only major current and future source of potable water in the Little Androscoggin River Basin. Its current high water quality must be maintained to insure a source of drinking water for future growth.

The many small streams, including Cole, Darnit and Stony Brooks, forming in the hills of Paris are of pristine quality, contain productive trout fisheries, and support the wildlife of the area. Any future contamination of these streams would detract from the aesthetic and general environmental quality of the area.

Finally, Paris Hill, as a registered historic site, is sensitive to any encroachment. Development within or adjacent to the area may detract from its value.

These environmentally sensitive areas should be protected or enhanced. Accordingly, sludge disposal alternatives likely to affect them detrimentally should be avoided.

III. SLUDGE DISPOSAL ALTERNATIVES

The choice of a procedure for disposing of waste solids from a water pollution control facility depends strongly on the physical and biochemical characteristics of the sludge in question. While solid wastes from most municipal treatment plants are sufficiently similar to allow a generic analysis of sludge disposal alternatives, sludge generated from the South Paris facility is distinctly different. A brief description of this sludge and its properties is therefore a useful preliminary to the assessment of disposal alternatives. A more comprehensive discussion of sludge-related analyses may be found in Appendix A.

A. Sludge Composition

Sludge currently produced at the South Paris treatment facility has a dry solids content of about 14 percent. This is substantially less than the design goal for combined (including secondary) sludge of 22 percent. Consequently, the plant is producing a larger volume of sludge than anticipated.

Nonvolatile solids, a measure of the inorganic content of the sludge, represent approximately one-third of its dry weight. The high level of nonvolatile solids results from the process chemicals applied to hides in the A. C. Lawrence tannery. More than 90 percent of the inorganic sludge constituents are calcium and chromium compounds.

Nitrogen ranges from 4,000 to 6,000 parts per million of wet weight in the sludge (about 3 to 5% on a dry weight basis). Approximately a third of this is ammonia nitrogen; the remainder is Kjeldahl nitrogen. The nitrite and nitrate nitrogen contents are negligible (less than 10 ppm).

Chromium is the dominant heavy metal in the sludge, representing more than 7 percent (as the metal) of its dry weight. Significant levels of lead occur because of corrosion in the tannery's mixing vats. Nickel, zinc, and copper are also present in trace concentrations.

By far the most significant environmental hazard of the sludge is its chromium content. The chemistry of chromium is sufficiently complex, and the toxicity of its compounds sufficiently uncertain, to make a precise determination of the hazards involved in disposing of the sludge highly necessary. Appendix B contains a detailed discussion of chromium chemistry and toxicity. The summary below focuses on facts pertinent to the sludge disposal problem.

The environmental and health chemistry of chromium concerns reactions and biological effects of its two most common oxidation states, the trivalent (Cr(III)) and the hexavalent (Cr(VI)). Cr(III) compounds are widely distributed in the environment, but at low levels. Soils and rocks, for example, contain from 1 to 1,000 parts per million (ppm) of chromium. Unlike many heavy metals, chromium does not appear to accumulate in plants, but vegetables and fruits may contain from 0.5 to 0.35 ppm. Inorganic Cr(III) compounds are generally insoluble under natural conditions. Thus, streams and rivers usually contain 10 parts per billion or less. Organic Cr(III) compounds exhibit a range of solubilities.

Cr(VI) is seldom found at detectable levels in the natural environment, primarily because it quickly reacts with organic matter and is thereby reduced to the trivalent state. However, Cr(VI) can be introduced to the natural environment through human activity and, if concentrations of oxidizable substances are low, may persist for long periods of time.

There is substantial agreement that Cr(III) salts have no adverse effects when taken orally, even at high concentrations. No long-term epidemiological studies of Cr(III) effects have been performed, but limited investigations of individual diseases have failed to correlate disease incidence with Cr(III) compounds in drinking water.

Cr(VI) salts, on the other hand, are toxic and carcinogenic. Lethal doses have been reported variously as from 0.5 to 10.0 grams. As little as 10 ppm in drinking water can cause nausea or vomiting. Occupational exposure to Cr(VI) compounds leads to increased incidence of lung, nasal, and other forms of cancer, as well as chronic skin irritations.

The consensus, then, is that Cr(III) is relatively benign, in itself. Nevertheless, Cr(III) compounds must be viewed as potentially hazardous substances because of their possible oxidation to Cr(VI) compounds. The Environmental Protection Agency's drinking water standard of 0.05 ppm applies to all oxidation states of chromium and reflects a substantial safety margin compared to known toxic concentrations.

All of the chromium in the South Paris wastewater treatment plant, including chromium in the liquid effluent and sludge, is in trivalent form. Field experience indicates that the dominant compound is amorphous chromium hydroxide. This compound is quite insoluble under nearly neutral conditions (pH of 7 to 8), and becomes even less soluble as it ages. Oxygen bridges form between chromium atoms, creating an even less soluble polymer structure. Thus, the principal danger of chromium contamination from the sludge would occur if acidic or alkaline conditions could allow significant leaching of chromium hydroxide.

To summarize, the sludge has a low solids content; of the solids it contains, about one-third are calcium carbonate and chromium hydroxide. Nitrogen levels are about average and may be a significant potential source of water contamination. The sludge contains trace concentrations of several heavy metals, besides the large amount of chromium. The form which the chromium takes, however, is rather inert chemically and relatively benign in terms of toxic effects.

B. Sludge Conditioning

Sludge disposal is the final component of a waste solids handling process that may include several other steps. In the South Paris plant, for example, solids handling includes gravity thickening, followed by polymer conditioning, and centrifuge dewatering. These are fundamental steps common to nearly all treatment facilities. However, further conditioning, stabilization, and reduction processes can be added if they are cost-effective or environmentally required.

Potentially applicable intermediate processes include:

- chemical disinfection
- composting
- anaerobic digestion
- chemical conditioning
- metal recovery

Chemical disinfection, through application of lime or chlorine, is generally intended to eliminate pathogens. In this case, however, such application would increase the solubility of the chromium hydroxide in the sludge, and could lead to oxidation to hexavalent chromium.

Composting and anaerobic digestion serve similar purposes, as well as helping to enhance the sludge's soil-conditioning characteristics. They might be considered in the present case, if the sludge were to be surface spread; they would be relatively expensive because of the high water content of the sludge.

Chemical conditioning involves the addition of special compounds to immobilize hazardous constituents and to improve the sludge's load-bearing properties. Chromium immobilization would permit disposal at an otherwise unsuitable site while improved load-bearing properties could permit area-filling of the sludge. Several types of proprietary conditioning systems are in commercial use. One, utilizing silicate-based chemicals has been applied to chrome-plating bath sludges that are similar in some respects to the South Paris sludge. Cost estimates for such a system are $200 thousand in initial capital and $160 thousand in annual operating expenses, mostly for the chemicals.

Metal recovery could be used as a means of reducing chromium content; however, such recovery could be made more economically earlier in the treatment plant process (or at the tannery) rather than from the sludge itself.

C. Sludge Disposal

Sludge disposal is usually considered in terms of two alternatives: incineration or disposal on land. Since incinerated ash must be disposed, the ultimate fate of the sludge is disposal on land in any case. However, incineration greatly reduces the volume and alters the chemical nature of the material to be disposed and is, in this sense, an alternative to direct land disposal.

1. Incineration

There are several proven technologies for incinerating sludge from municipal treatment plants. The South Paris sludge, however, is so unusual that the efficacy of these technologies cannot be assessed without actual combustion tests. In addition, the South Paris sludge has several characteristics that significantly increase the cost of incineration over that of more normal sludges. These issues are discussed in detail in Appendix E. Conclusions are summarized below.

Major drawbacks to incineration are the high water content of the sludge, and the large amounts of inorganic constituents, particularly heavy metals. The sludge contains about one-third less dry solids than ordinary municipal sludges -- less than half the amount necessary for self-supporting combustion. All water in the sludge, of course, is energy-consuming during incineration. Inorganic constituents -- one-third of the sludge's dry weight -- do not demand or produce major amounts of energy during combustion. But their presence reduces the heating value of the sludge. Finally, incineration will convert the chromium in the sludge to the toxic hexavalent state. Because of this, stack gas scrubbing and conditioning of the incinerated ash to immobilize chromium prior to disposal would be required.

While conventional stack gas scrubbers should be effective in this instance, chemical conditioning of the ash is an unproven technique. There is no evidence that hexavalent chromium in the ash could be fully immobilized by any available conditioning system. Thorough testing of a proposed conditioning approach would be necessary to determine its effectiveness.

The economics of incinerating this sludge are unappealing even if we make the assumption that the solids content of the sludge will eventually be increased to 20 percent. Incineration (with energy recovery) would require supplemental fuel equivalent to 500 gallons of oil per day. This translates to an annual cost of greater than $50,000 for fuel alone.

Supplemental fuel requirements could be satisfied by other solid wastes, for example, municipal refuse or sawmill by-products, which have significant heating value. If 15 to 20 thousand pounds per day of municipal refuse were used, they could supply sufficient energy to fully combust the South Paris sludge.

There are, however, several constraints to implementing a combined incineration program. Combined incineration requires more complex and expensive waste handling and incineration equipment. It requires a consistent volume and mix of solid waste inputs seldom found in small, nonurban areas. Finally, the costs of chemical ash conditioning would be larger, since these are proportional to the quantity of ash produced. In any case, combustion of other solid wastes would serve primarily to subsidize costs for incineration of the sludge.

Estimated costs for incinerating the sludge alone are $600 thousand in initial expenses and $120 thousand per year for operating costs, excluding ash disposal. The principal potential benefits are minimization of water quality impacts (if Cr in the ash can be immobilized) and significant reduction in land requirements for final solid waste disposal.

2. Land Disposal

Land disposal falls into three broad classes: surface spreading, area filling, and trenching. The choice among these methods depends strongly on the character of the solids to be disposed and therefore on the processes used to produce these solids.

In surface spreading, sludge is applied to existing land contours in a relatively thin layer. It may be left on the surface or incorporated in the soil by plowing. In either case, microbial decomposition breaks down complex organic constituents to release basic nutrients such as nitrogen, which are taken up by vegetation and built back into protein compounds. When sludge has been stabilized, surface spreading may be used for crops intended either for direct human consumption or for animal consumption with appropriate precautions. Unstabilized sludge, however, contains pathogenic organisms and is typically used to condition soil for crops such as legumes or grasses or with forest sites.

Area-filling involves the application of thick layers of sludge to specially prepared sites. Layers of sludge and cover material may be alternated until the site is fully utilized, after which a final layer of cover material is spread and the area revegetated. Essentially the same practice is followed in sanitary landfills for municipal refuse. Because of the cover material, conditions within the sludge layers remain largely anaerobic and decomposition occurs gradually, with no positive effect on soils or vegetation.

Finally, sludge can be buried in trenches constructed specifically for this application after which a suitable layer of cover material is deposited. The principal distinction between area filling and trenching is intensity of site utilization. Trenching involves a single layer of sludge and requires that sufficient space be left between trenches to avoid collapse of trench walls. Trenching is used primarily for sludges that are insufficiently dense to be area-filled. It may also be used, however, to limit the total loading of pollutants concentrated in a site.

In evaluating alternative combinations of these intermediate process steps and final disposal methods, the most significant limiting factor is the high chromium concentration in the current sludge. It effectively eliminates the possibility of surface spreading. While plants do not appear to concentrate or accumulate chromium, they will take it up when exposed to high concentrations. The risks both to crops and ultimately to humans are uncertain, but sufficient to rule out this alternative.

EPA has not as yet established a maximum concentration for chromium in sludges to be surface-spread. Their recommended levels for other heavy metals, however, range from 10 ppm for mercury and cadmium to 2,000 ppm for zinc. Even 90% chromium removal from the South Paris sludge would leave 7,000 ppm of Cr in the sludge, far in excess of acceptable levels for other heavy metals. If surface spreading is unacceptable, composting or anaerobic digestion of the sludge is unnecessary.

In addition, the current sludge has insufficient load-bearing capacity to permit area filling. This is largely the result of its high water content, and means simply that deposited sludge could not safely support the weight of heavy equipment used in area filling. Thus, trenching is the only viable land disposal method for the current sludge.

D. Sludge Trenching

Trenching of unconditioned sludge is the simplest disposal alternative. The environmental impacts of sludge trenching, however, are highly situation specific. They depend on sludge composition, site characteristics, and operating conditions.

Analyses of topographic, geologic, and soils data for South Paris indicate that the town contains essentially two kinds of potential landfill sites. Upland areas on he sides and tops of hills on both sides of the Little Androscoggin River represent one class of site. The hills are composed of fissured bedrock overlain by a stratum of glacial till -- a heterogeneous mixture of sand, gravel, and boulders. The till was compacted by glacial action and has very low permeability. However, its upper surface has weathered since glaciation, leaving a permeable cover from one to several feet in depth.

As a result, water from rainfall or spring thawing can percolate only to the surface of the compacted till (or hardpan), after which it flows downhill along this surface until it enters streams or the groundwater system under the valley floor. Lenses of groundwater within a few feet of the surface are therefore prevalent in upland areas.

Lowland portions of Paris constitute a second type of potential site for land disposal. The lowlands lie on the valley floor of the Little Androscoggin River Basin at the base of the surrounding series of hills. In these areas, the bedrock and initial deposits of till have been covered by sand and gravel carried by glacial melting. These sand and gravel deposits can reach depths of 100 feet or more and are highly permeable. Precipitation quickly percolates through this layer until it intercepts the water table, typically at depths greater than 20 feet. This groundwater flows eventually through the regional aquifer beneath the Little Androscoggin River in a general southerly direction.

In terms of trenching of sludge, upland sites suffer from water tables within a few feet of the surface. Soils of lowland sites have the disadvantage of low content in constituents with significant cation exchange capacity, i.e., materials that have the ability to react chemically with and remove dissolved pollutants leached by percolating water from sludge deposits.

An alternative to trenching or burying the sludge at South Paris would be utilization of a regional landfill for disposal of the sludge. However, such an option is not available in the immediate future.

The general unsuitability of the South Paris area does not eliminate trenching of unconditioned sludge as a viable alternative. Rather, it implies a need for detailed, situation-specific analyses to determine if the kinds of landfill sites available in Paris are, or can be made, environmentally acceptable. Such analyses, of course, require focusing on specific parcels of land. The parcels selected were the A. C. Lawrence site, a typical lowland area, and the Ryerson Hill site, a typical upland area. Both sites had been subjected to previous study, establishing an initial base of supportive data. The Lawrence site, furthermore, has been the dumping area for some 20 years of tannery sludge and provided the opportunity of direct study of the impacts of sludge under actual conditions.

IV. SLUDGE TRENCHING

A. The A. C. Lawrence Site

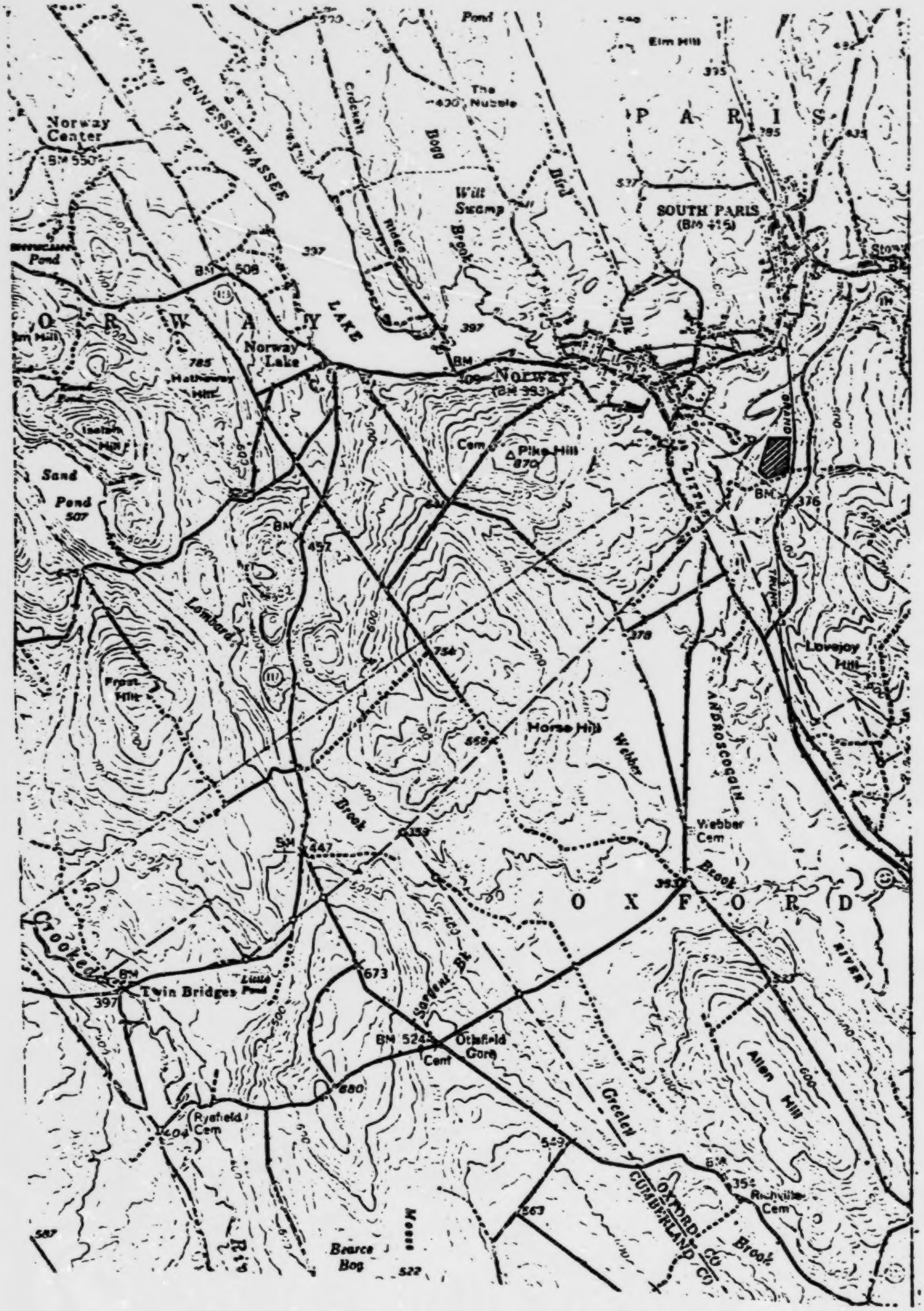
The A. C. Lawrence site, shown in Figure 1, lies between Oxford Street to the east and the Little Androscoggin River to the west, about 3.5 miles (by road) from the treatment facility. It comprises some 49 acres owned by the A. C. Lawrence Leather Company. The company has employed the site for disposal of sludge dredged from its holding lagoons since the late 1950's. In 1975, however, the tannery wastewater was diverted to the South Paris Water Pollution Control Facility.

The Paris Utility District's initial application to continue using the site for sludge trenching was denied by the Board of Environmental Protection on the basis primarily of soil conditions and proximity to an aquifer. For the past two years, however, treatment plant sludge has been trenched on the site under temporary permits.

The current investigation was aimed primarily at determining the magnitude and extent of environmental impacts from historical use of the site. It included analysis and characterization of:

- geology and stratigraphy
- hydrology
- soils composition and properties
- pollutant mobility
- groundwater quality

A full description of these analyses may be found in Appendix C.



Pond
Elm Hill
The Nubble
PARIS
Norway Center
BM 550
PENNESSEWASSEE
Crockett
Bog
Brook
Bird
Will Swamp
SOUTH PARIS
Pond
LAKE
NORWAY
Norway Lake
Norway
Hathaway Hill
Pike Hill
870
Sand Pond
507
Lombard
Frost Hill
Horse Hill
Webber
Lovejoy Hill
ANDROSCOGGIN
Webber Cem
Brook
OXFORD
Crooked
Twin Bridges
Little Pond
Sargent Bk
Otisfield Gore
BM 524
Cem
Greeley
Allen Hill
RIVER
Ryefield Cem
OXFORD
CUMBERLAND CO
Richville Cem
Brook
Bearce Bog
Moose

Fig. 1: Location of the A. C. Lawrence site.

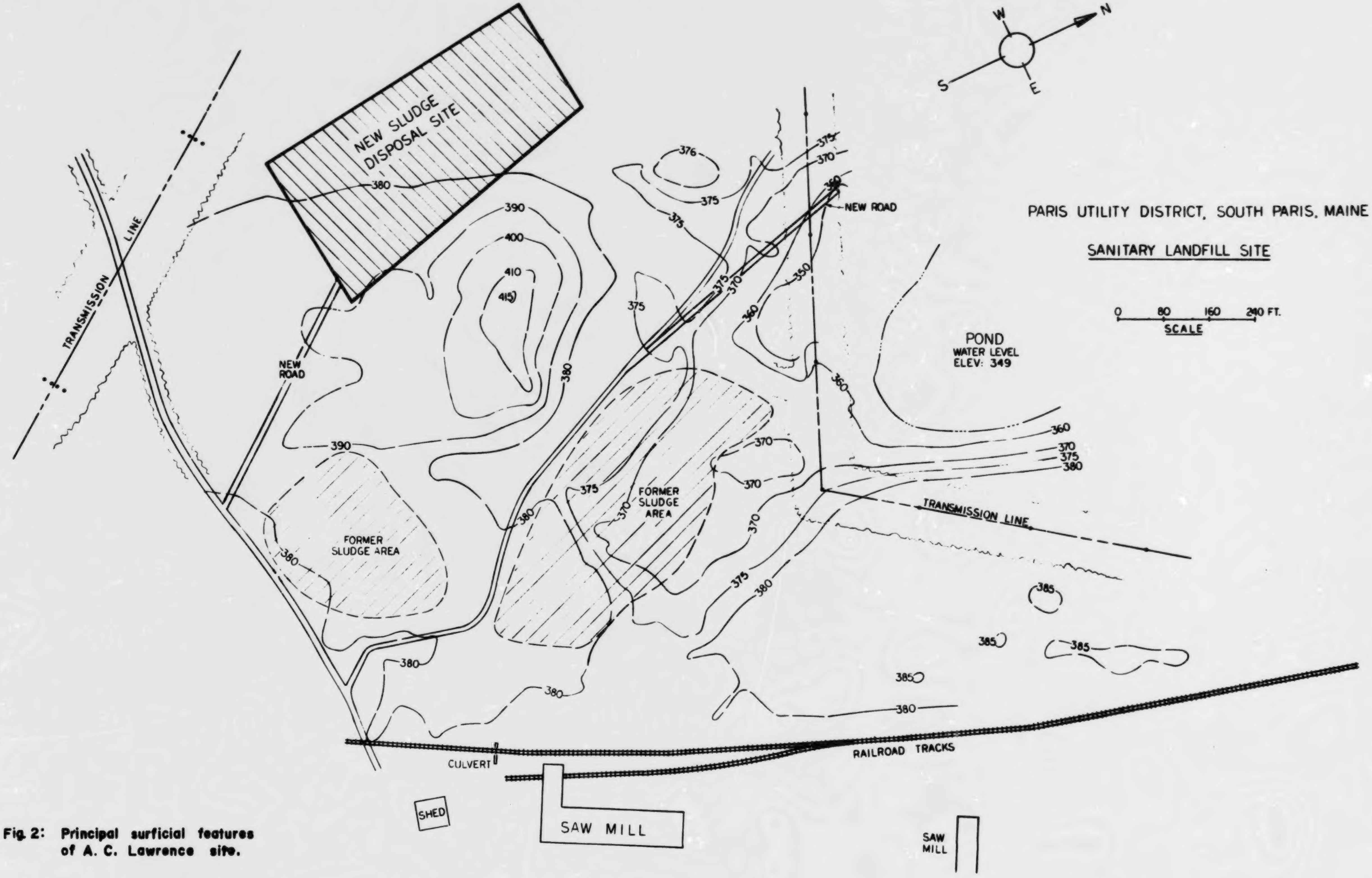
Figure 2 shows the principal surficial features of the Lawrence site, including the locations of historical sludge dumping areas and the current trenching area. The general topography is irregular; a small knoll rises some 60 feet near the center of the site, separating the old and current fill areas. A small pond borders the northern edge of the site.

Figure 3 is a larger scale map of the site and its surroundings on which the locations of test wells are noted. The wells provided soil and sediment samples, stratigraphic data, and heights of the water table; several were also subjected to pumping tests to collect hydrological information. The arrows superimposed on the map indicate the general directions of groundwater flow.

Permeable sand and gravel deposits constitute the cover material for most of the area. The knoll, however, represents an outcrop of bedrock and impermeable till that serves as a hydrologic barrier, diverting groundwater on its east side in a northerly direction. Near the river, the barrier ends and the groundwater reverses its flow, moving southerly under and on both sides of the river.

Groundwater lies under the historical dumping areas at depths of 20 to 35 feet and flows north. There is no permanent water table under the current trenching area.

Groundwater quality was monitored at locations situated hydrologically downstream of the sludge disposal areas. These locations included:


W
N
S
E
PARIS UTILITY DISTRICT, SOUTH PARIS, MAINE
SANITARY LANDFILL SITE
0
80
160
240 FT.
SCALE
NEW SLUDGE DISPOSAL SITE
TRANSMISSION LINE
NEW ROAD
NEW ROAD
POND
WATER LEVEL ELEV: 349
FORMER SLUDGE AREA
FORMER SLUDGE AREA
TRANSMISSION LINE
RAILROAD TRACKS
CULVERT
SHED
SAW MILL
SAW MILL
376
375
375
375
370
360
350
380
390
400
410
415
375
375
370
360
380
390
360
370
375
380
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380

Fig. 2: Principal surficial features of A. C. Lawrence site.

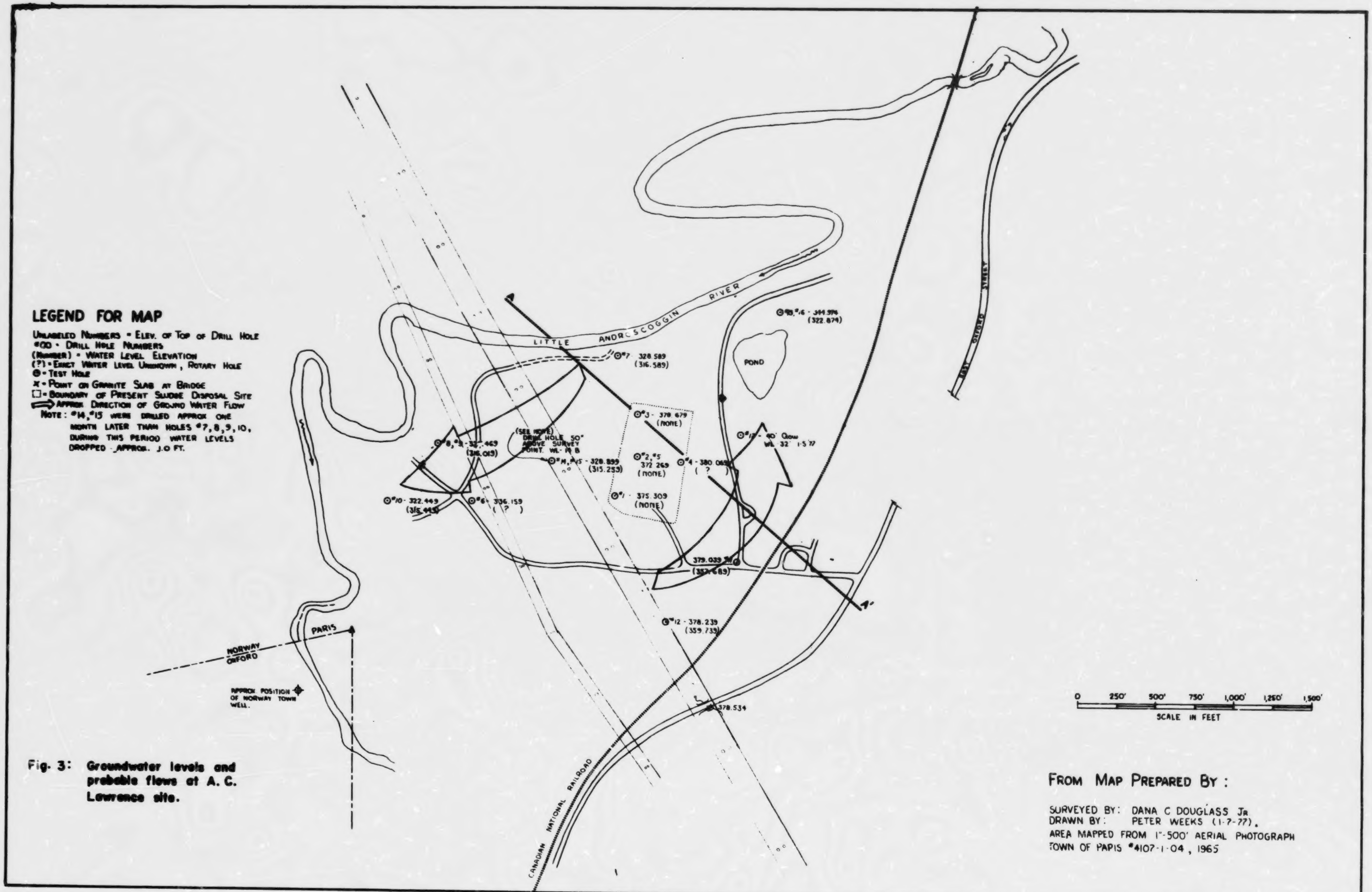
LEGEND FOR MAP
UNLABELED NUMBERS = ELEV. OF TOP OF DRILL HOLE
#00 - DRILL HOLE NUMBERS
(NUMBER) = WATER LEVEL ELEVATION
(?) = EXACT WATER LEVEL UNKNOWN, ROTARY HOLE
⊙ = TEST HOLE
✕ = POINT ON GRANITE SLAB AT BRIDGE
☐ = BOUNDARY OF PRESENT SLUDGE DISPOSAL SITE
⇨ APPROX. DIRECTION OF GROUND WATER FLOW
NOTE: #14, #15 WERE DRILLED APPROX ONE MONTH LATER THAN HOLES #7, 8, 9, 10, DURING THIS PERIOD WATER LEVELS DROPPED APPROX. 1.0 FT.
LITTLE ANDROSCOGGIN RIVER
POND
#7 328.589 (316.589)
#13, #16 - 344.976 (322.874)
#3 - 378.679 (NONE)
#8, #9 - 32_.469 (316.019)
(SEE NOTE) DRILL HOLE 50" ABOVE SURVEY POINT. WL- 19 B
#14, #15 - 328.899 (315.253)
#2, #5 372.269 (NONE)
#4 - 380.069 (?)
#17 - 40' Glow WL 32' 1-5-77
#10 - 322.449 (315.449)
#6 - 336.159 (?)
#1 - 375.309 (NONE)
379.039 (352.689)
#12 - 378.239 (359.739)
378.534
A'
PARIS
NORWAY
OXFORD
APPROX POSITION OF NORWAY TOWN WELL.
CANADIAN NATIONAL RAILROAD
EAST OXFORD STREET
0 250' 500' 750' 1,000' 1,250' 1,500'
SCALE IN FEET

Fig. 3: Groundwater levels and probable flows at A. C. Lawrence site.

FROM MAP PREPARED BY:

SURVEYED BY: DANA C DOUGLASS JR
DRAWN BY: PETER WEEKS (1-7-77).
AREA MAPPED FROM 1"-500' AERIAL PHOTOGRAPH
TOWN OF PARIS #4107-1-04, 1965

- north of the historical dump areas (well #13)
- west of the current trenching area (well #14)
- northwest of the Lawrence property, where the groundwater has reversed its flow (wells 7, 8, 9 and 10).

In addition, test wells were drilled directly through a historical sludge deposit (wells #17 and #18), and soils and groundwater were analyzed to determine a vertical profile of pollutant concentrations beneath the sludge.

These analyses revealed that the present quality of groundwater in the general vicinity of, or directly under, the sludge disposal areas is not significantly degraded. Only groundwater from well #7 showed quality that was less than the general groundwater quality of the region. This is an impact of the Norway municipal dump -- located about 400 feet directly across the river -- rather than of sludge deposits on the Lawrence site.

The absence of groundwater quality degradation at historical dump areas appears to be a result of good permeability of the soils and of large flows of groundwater in the area. High permeability on the site allows rapid infiltration of rainwater, so that contact time with the sludge is limited. The sludge itself, when wet, is relatively impermeable. Whatever leachate is generated, is substantially diluted by a large volume of groundwater flow. The overall result has been little or no deterioration of the groundwater quality at the Lawrence site.

Examination of soils at the historical dump site shows that chromium is found throughout the sand down to the water table. The most probable origin of the vertical distribution of chromium at the old site is filtering of wet sludge by the bed of sand on which it was deposited. Contrary to current practice, older sludge was not dewatered. Effluent from the tannery was allowed to settle in ponds and the wet sediment was then removed and dumped at the Lawrence site. It is probable that appreciable liquid flowed from the sludge eventually entering the groundwater. Particles containing chromium were carried downward by this flow, aided perhaps by infiltrating rainwater, and some were trapped and accumulated at the water table. However, chromium in these particles has remained insoluble and did not degrade water quality.

Currently produced sludge is not expected to follow this behavior. After centrifuging, the physical characteristics of the sludge are essentially those of a gel. Accordingly, no liquid flow from the sludge is expected nor is it likely that rainwater will percolate through the sludge. Most likely, infiltrating rainwater will flow along the surface and sides of current sludge deposits. Accordingly, these deposits are expected to generate much less seriously contaminated leachate than was probably the case with the historical deposits at the Lawrence site.

The principal conclusion of these analyses is that the Lawrence parcel and its immediate surroundings are an acceptable location for trenching the sludge.

The parcel of land currently owned by the A. C. Lawrence Company contains insufficient land for long term (20 years) operation. Because of the irregular topography, and ledge outcrops and large boulders on the knoll, only some 15 acres of useable land remain. At present sludge production volumes, this represents a very limited operating life. Land available to the south of the Lawrence parcel with similar geologic and hydrologic properties could provide sufficient area for expansion of the site to meet a 20-year design life.

Initial costs for continued use of the Lawrence site (including expansion) are estimated to be $36,000. Total operating costs for the site are approximately $25,000 per year. Table 1 provides a breakdown of these cost estimates.

B. The Ryerson Hill Site

The Ryerson Hill site was analyzed intensively prior to and during the Public Hearings for use as a sludge disposal site. The principal focus of the current study, therefore, was a review and independent evaluation of previously collected data, analyses, and conclusions.

The Ryerson Hill parcel, shown in Figure 4, lies some 8 miles (by road) from the treatment facility, in the northeastern corner of Paris. It is at an elevation of 1,000 to 1,150 feet above sea level, on the northern side of Ryerson Hill, some 600-800 feet above the elevation of the treatment facility.

Figure 4 displays the principal surficial features and topography of the general area near the site. The terrain at the site is regular, sloping gently downward to the north at an average 5 percent grade. The site contains some 52 acres of land.

Results of test augering confirm the geologic and hydrologic pattern expected of upland areas. The initial soil horizon contains

Table 1

Cost Estimates for Lawrence Site Sludge Trenching

Capital Costs[1]		Operating Costs[4]	
Land[2]	$ 7,000	Trucking[5]	$ 4,400
Excavation and Clearing	10,000	Labor[6]	15,000
Miscellaneous Site Preparation	3,500	Clearing	4,500
Monitoring Wells	3,000	Miscellaneous	1,000
Engineering	10,000	Total	$24,900
Contingency[3]	2,650		
Total	$36,150		

---

[1] Excludes currently owned container truck and backhoe.

[2] Assumes 35 additional acres purchased at $200/acre.

[3] Estimated as 10% of engineering and site preparation costs.

[4] Excludes backhoe costs.

[5] Assumes 70 miles per day, 5 days per week, 50 weeks per year with truck operating cost of $0.25 per mile (total rounded to nearest $100).

[6] Assumes full-time backhoe operator and half-time container truck operator (operator has other duties at treatment plant); salaries and fringe benefits at $10,000 per year per man.

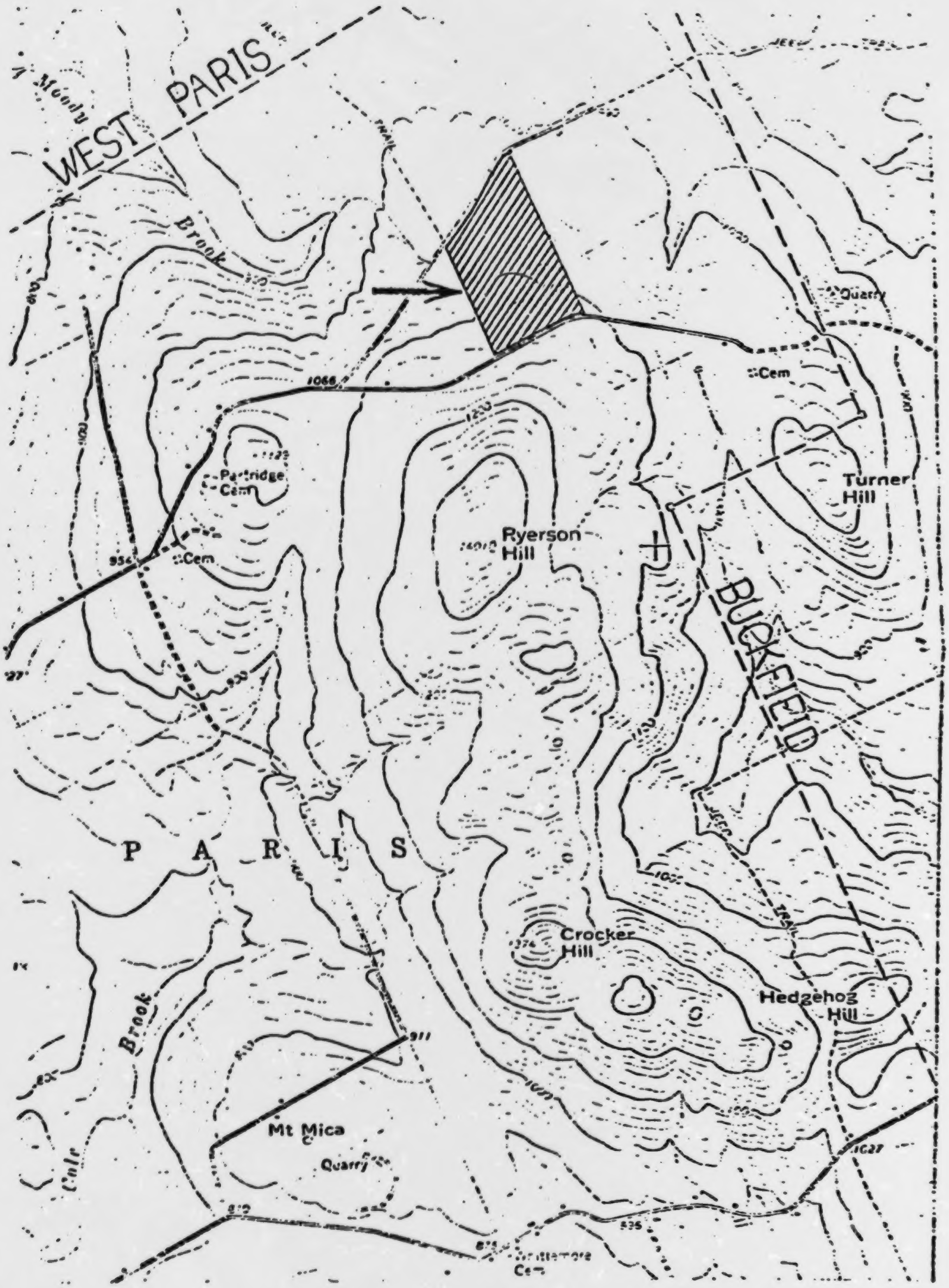
WEST PARIS
Moody
Brook
Partridge Cem
Cem
Ryerson Hill
Turner Hill
Quarry
Cem
BUCKFIELD
PARIS
Crocker Hill
Hedgehog Hill
Brook
Cole
Mt Mica
Quarry
Whittemore Cem
1066

Fig. 4: Location of the Ryerson Hill site.

moderately permeable sand silt mixtures and silts. Lenses of groundwater move through this stratum, frequently within 15 inches of the surface. Beneath this water, starting at depths of 2 to 5 feet, there is highly impermeable hardpan, underlain, in turn, by bedrock. Groundwater in the upper soil stratum moves downhill, eventually entering several streams and brooks to the north.

Lowering the perched water table would be a necessary first step if the Ryerson Hill parcel were to be used for sludge trenching. To accomplish this, a drainage system was designed to intercept surface and perched groundwater flows upstream of the site, redirect them along the site peripheries, and eventually discharge the intercepted water below the landfill area at the site's northern boundary. The design included an 8 foot buffer zone between the peripheral drains and the closest sludge trenches.

This engineering plan was a focus of controversy during hearings on the Ryerson Hill site. Of principal concern were:

- the efficacy of the groundwater control system
- leachate movement through the buffer zone into the peripheral drains
- impacts of lowering the groundwater table on surrounding areas.

These issues are discussed in detail in Appendix D. The following conclusions are relevant.

A properly designed and constructed system for groundwater control can be effective. However, major problems can arise if groundwater originating in bedrock fissures, possibly under pressure, is encountered on the site, since such sources would be isolated by hardpan from the drains. While there is no specific evidence of any connection between bedrock-contained groundwater and the perched water table on the Ryerson Hill site, such occurrences are not uncommon in upland portions of the region. They are difficult to identify in advance. If such springs are present, they could render portions, or conceivably all, of the site unsuitable for sludge trenching.

Assuming that the drainage system operated effectively, leachate would still be generated as a result of precipitation on the site itself. Rain will infiltrate the upper soil horizon and drain along the surface of the hardpan, across the top of trenched sludge, and into the peripheral drains. Contact time between this water and the sludge will be relatively long, because the path of flow lies along the length of each trench (40 feet). At the same time, however, there may be ample opportunity for leachate contact with the soils in the buffer strips separating the peripheral drains from the nearest trenches, and throughout the site. Therefore, the quality and composition of the resulting water flowing from the site are difficult to predict.

The impact of removing the perched groundwater on surrounding areas should be relatively small. Although the peripheral drains would be 11 feet deep, they would actually drain only the upper 2 to 5 feet. The probable change in hydrostatic head is thus a few feet, with correspondingly small effects on the surrounding water table. It should be noted that the principal mechanism for draining the site itself is interception and diversion of flow from upstream. The conclusion that effects on the surrounding water table are relatively small does not, therefore, mean that the drainage system would be ineffective. It should also be noted that the effect of the peripheral drains on surrounding areas will be nearly as pervasive as on the site, i.e., drainage will be approximately symmetrical.

On the whole, then, the Ryerson Hill site could be operated in an environmentally acceptable fashion. Leachate quality would have to be monitored and if a 'bathtub' condition appears to be developing for the trenched sludge, special measures would have to be taken. This conclusion assumes no extensive interactions between the perched water table and any groundwater contained in the underlying bedrock. Isolated interactions could be controlled on a case by case basis, with some loss of available land and at addition expense. The only practical means of determining the extent of such interactions is to attempt to drain the site as planned. Clearly, this is a costly way of establishing whether the site is acceptable.

The risks noted above are difficult to incorporate in a formal way in cost estimates for the site. Table 2 presents estimated initial and operating costs if the drainage system operates as designed. The drainage system itself is the most expensive item. Further, the distance of the site from the treatment facility is large enough to require a storage and maintenance garage for heavy equipment at the site as well as the use of two container trucks to transport sludge. Initial and operating costs for the Ryerson Hill site are estimated to be significantly

Table 2

Cost Estimates for Ryerson Hill Site Sludge Trenching

Capital Costs[1]		Operating Costs[4]	
Land[2]	$ 10,400	Trucking[5]	$10,000
Excavation and Clearing	10,000	Labor[6]	25,000
Drainage Ditch Construction	55,000	Clearing	4,500
Drain Piping	4,000	Miscellaneous	2,000
Maintenance Building and Slab	20,000	Total	$41,500
Sand and Gravel Ditch Filler	2,000		
Miscellaneous	3,500		
Container Truck	25,000		
Engineering	15,000		
Contingency[3]	11,000		
Total	$155,900		

---

[1] Excludes currently owned backhoe and one container truck.

[2] Purchase price.

[3] Assumes 10% of engineering and site preparation costs (rounded).

[4] Excludes backhoe costs.

[5] Assumes 160 miles per day, 5 days per week, 50 weeks per year with truck operating cost of $0.25 per mile.

[6] Assumes full-time backhoe operator, one full-time container truck operator, and one half-time container truck operator (who has other duties at treatment plant); salaries and fringe benefits assumed at $10,000 per year per man.

higher than for the Lawrence site. The major risk, of course, is that expenditures for the drainage system -- some $60,000 -- could be wasted. A similar risk, however, will probably exist for other upland sites.

V. ENVIRONMENTAL IMPACTS

A. Cost Effectiveness and Environmental Risks

Each of the alternatives discussed is, in a broad sense, environmentally acceptable. Their cost-effectiveness and the uncertainties or risks they present are summarized in Tables 3 and 4.

Because the current sludge is relatively stable and its constituents largely immobile, chemical conditioning and incineration would impose major costs with little reduction of environmental risks. The principal potential cost advantage -- reduction in land requirements for a final dipsosal area -- is insufficient in this instance to offset the extra expense of incineration. Further, uncertainties remain as to the combustion properties of the sludge and the efficacy of conditioning the ash.

Trenching in a special landfill is clearly the least costly disposal method. The use of an upland site, like the Ryerson Hill parcel, involves substantial costs for groundwater control. The principal environmental risk would be failure of the control system, in which case significant contamination of streams and brooks below the site may occur.

Data collected in this study show that significant deterioration of groundwater quality did not occur at the Lawrence site even with wet sludge haphazardly deposited on the site. The risk of adverse impacts on groundwater is less with currently produced sludge and with suitable operating precautions. Sludge trenching at the Lawrence site has lower

Table 3

Cost Comparison of Viable Alternatives

Alternative	Trench Current Sludge		Incinerate Sludge, Landfill Ash		Condition and Landfill Sludge	
	At Lawrence Site	At Ryerson Hill Site	At Lawrence Site	At Ryerson Hill Site	At Lawrence Site	At Ryerson Hill Site
Capital Costs ($ thousand)						
at Treatment Plant	-	-	600	600	200	200
at Landfill Site	36	156	36	156	36	156
Total	36	156	636	756	236	356
Operating Costs ($ thousand/yr)						
at Treatment Plant	-	-	120	120	160	160
at Landfill Site	25	42	23	37	25	42
Total	25	42	143	157	185	202
Projected Landfill Site Life (years)	15-20	15-20	30-40	30-40	20-25	20-25

Table 4

Comparison of Uncertainties of Viable Alternatives

Alternatives	Uncertainties				Comments
	Principal Operating Uncertainty		Principal Environmental Uncertainty		
	Form	Magnitude	Form	Magnitude	
Trench Sludge at Lawrence Site	-	-	Groundwater Contamination	Low	No significant impact of old sludge deposits
Trench Sludge at Ryerson Hill	Groundwater Control	Moderate	Stream Contamination	Low	Groundwater control problems could increase costs, but their solution would eliminate most environmental uncertainties
Incinerate Sludge, Landfill Ash	Combustion Properties of Sludge, Effectiveness of Ash Conditioning	Moderate to High	Groundwater or Stream Contamination	High	Environmental uncertainty higher because ash would contain hexavalent chromium

cost than at upland locations. Accordingly, it seems desirable to extend the geologic and hydrologic studies to areas immediately south of the A. C. Lawrence site in order to establish whether continued use and expansion of the site is feasible and desirable.

B. Environmental Impacts of Sludge Trenching

Certain impacts of sludge trenching are general while others are site-specific. The land employed for sludge trenching will be, from a practical viewpoint, permanently committed to that use. The buried sludge decomposes slowly; total decomposition will take several decades. Further, the concentration of chromium beneath the site will remain above ordinary levels much longer. Ultimately, of course, the area can be reclaimed, but when this might be possible is uncertain.

Sludge trenching will disrupt habitats of wildlife species occupying the selected site. Potentially affected species include deer, ruffed grouse, fisher woodcock, and pheasant. The disruption will be limited to the site itself. The surrounding areas include ample resources to support displaced wildlife populations. No endangered species are known to be involved.

The aesthetic impact of sludge trenching can be slight if the site is relatively isolated, with little direct visual contact to residences, businesses, or public roads. Open sludge trenches produce some odor, noticeable on the site itself, but daily covering minimizes this effect. Covered trenches produce no noticeable odor. Heavy equipment noises will occur on-site, but will be highly localized. Trees in the immediate vicinity of trenches will have to be removed and this area should remain cleared for the foreseeable future. However, grass can be planted over the trenches and the periphery of the site can be kept forrested to minimize visual impacts.

Site specific effects include effects on water quality, effects arising from trucking the sludge to the site, and energy consumption associated with transporting and handling the sludge. A choice of an upland site, such as Ryerson Hill, entails longer hauling trips. It implies, therefore, higher energy consumption and greater noise and visual impacts on residential areas of South Paris. Choice of a lowland site, such as the A. C. Lawrence site, reduces such impacts.

Potential water quality impacts depend on site location. In the case of an upland site, potential effects are on water quality of surface streams. As discussed in some detail earlier, potential impacts can be minimized or eliminated by proper engineering design at the Ryerson Hill site.

Water quality impacts at a lowland site include potential effects on the Little Androscoggin River and on groundwater flowing beneath such areas. The evidence gathered during this study suggests that sludge disposal at one lowland site, the A. C. Lawrence site, had no significant, permanent effect on groundwater quality. Impacts on the Little Androscoggin River, if any, are totally overwhelmed by effects of the direct discharge into the river of the effluent of the wastewater treatment plant.

C. Other Considerations

Irreversible or irretrievable commitment of resources for land trenching are limited to the site itself which will not be useable for other purposes for the foreseeable future. A long range productivity loss from commitment of this resource is more than balanced by conservation of resources implied by the choice of trenching over other methods of disposal, for example, incineration.

Impacts on archeological resources depend on the site chosen. Neither the A. C. Lawrence nor the Ryerson Hill site has any archeological significance (see Appendix G).

APPENDIX A

CHARACTERIZATION OF SLUDGE DISPOSED BY THE SOUTH PARIS WASTE WATER TREATMENT PLANT

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APPENDIX A

CHARACTERIZATION OF SLUDGE DISPOSED BY THE SOUTH PARIS WASTE WATER TREATMENT PLANT

The sludge produced by the South Paris wastewater treatment plant is mainly a tannery waste. According to the design goals for the plant, primary sludge (3 to 6% solids) was to be dewatered by centrifuging to 30 to 35% solids; the waste activated sludge (1% solids) was to be dewatered to 12% to 13% solids. The combined sludge was expected to contain about 22% solids.

The design goals have not been met as yet (1976). Dewatered primary sludge samples taken during October 1976 had solids contents of about 14% (see Table A-1). Secondary sludge was not produced; the plant was bulking and secondary sludge was wasted into the effluent. Accordingly, the description of the sludge given below refers to primary sludge only. However, since primary sludge is expected to constitute over 90% of the sludge to be produced when the plant is in full operation, the results given below should be representative, particularly in terms of chemical composition, of the sludge to be produced eventually by the plant.

1. Physical Characterization

Samples of sludge were obtained on 10/6/1976, 10/27/1976 and 10/28/1976. As noted above, all were samples of primary sludge, that is, did not include solid waste from the secondary (biological) stage. The sample of 10/6/1976 was a grab sample taken from a trench at the A. C. Lawrence landfill site. The samples of 10/27/1976 and 10/28/1976 were obtained at the plant (sampling every 2 hrs) and mixed into composites for each of these two days of operation.

Table A-1

Solids Content(1)

Date	Sample	% Solids
10/06/76	Grab	12.0
10/27/76	Grab-1	13.4
	Grab-2	13.1
	Grab-3	13.7
	Grab-4	13.9
	Grab-5	14.0
	Grab-6	14.3
	Grab-7	14.1
	Composite	13.8
10/28/76	Grab-1	14.4
	Grab-2	14.2
	Grab-3	13.4
	Grab-4	13.3
	Grab-5	15.4
	Composite	14.1

---

(1) Solids content was determined by drying at 105-110°C for 24 hrs. No difference was found when the drying time was extended to 48 hrs.

(a) Solids Content

Solids content was determined by drying to constant weight at 105-110°C. In general, 24 hrs of heating was sufficient, no difference in weight being observable when the drying time was extended to 48 hrs.

The solids content ranged from 12.0 to 15.4% by weight. The average solids content (composite samples) was about 14%. Information provided by the plant suggests that the level of solids content has not changed significantly from 14% over its approximately one year of operation.

(b) Non-volatile Solids

Non-volatile solids were determined by heating to 600°C until constant weight was achieved. This temperature is somewhat above the decomposition temperature of $CaCO_3$ (the dissociation pressure of $CaCO_3$ at 600°C is 3 mm Hg of CO_2) and some decomposition of $CaCO_3$ probably occurred. Results, summarized in Table A-2, show that approximately 35% of the dry solids are inorganic (non-volatile), the balance being presumably organic material.

Table A-3 also shows the distribution of inorganic, non-volatile matter derived from the chemical analysis (see Section A-2 below) assuming that after heating to 600°C, Ca is present essentially as $CaCO_3$, Cr as Cr_2O_3, Fe as Fe_2O_3, Mg as MgO, and Na as NaCl. The contribution of other constituents (essentially Cu, K, Mn, Pb and Zn) is less than 0.15 wt% and can be neglected in the mass balance. As can be seen from Table A-3, non-volatile solids derived from the chemical analysis amount to about 36%, in good agreement with the value of 35% determined directly. The slightly greater value obtained from the chemical analysis suggests some decomposition, as expected, of $CaCO_3$ to CaO upon ignition to 600°C. If this discrepancy were entirely due to this source, it would imply about 10-20% conversion of $CaCO_3$ to CaO upon heating at 600°C.

(c) X-Ray Analyses

Both wet and dried sludge was examined by X-ray analysis. Well-defined lines corresponded to $CaCO_3$. A weak peak at 3.34 Å may be due to

Table A-2

Non-Volatile Solids Content of Sludge(1)

Date	Sample	% Non-Volatile Solids
10/06/76	Grab	35.5
10/28/76	Composite	33.1

---

(1) Determined by heating to constant weight at 600°C. Percentages are based on dry solids content of sludge.

Table A-3

Composition of Non-Volatile Solids(1)

Element(2)	% Wt	Assumed Compound	% Wt
Ca	4.57	$CaCO_3$	11.4
Cr	7.34	Cr_2O_3	21.4
Fe	0.27	Fe_2O_3	0.8
Mg	0.16	MgO	0.3
Na	1.02	$NaCl$	2.6
		Total	36.5

---

(1) Percentages are based on dry weight.

(2) Determined by chemical analysis of sludge.

$Cr(OH)_3$. A very broad peak ($14° < 2\theta < 24°$) may be due to amorphous chromium hydroxide.

2. Chemical Composition

(a) Metals Content

Potentially hazardous wastes of tannery sludge are chromium, copper, lead and zinc ("Assessment of Industrial Hazardous Waste Practices - Leather Tanning and Finishing Industry," SCS Engineers Inc., EPA Contract 68-01-3261, September, 1976). Accordingly, the sludge produced by the South Paris wastewater treatment plant was analyzed for these metals, and for other metals which may be present, by atomic absorption. The results of the analyses are given in Table A-4. As noted previously, the major constituents (Ca, Cr, Fe, Mg and Na) account quantitatively for the non-volatile solids content of the sludge.

(b) Other Constituents

Sludge samples were also analyzed for ammonia and Kjeldahl nitrogen, for total phosphorous, for sulfide, and for chloride. All analyses were done in triplicate. Standard methods ("Standard Methods for the Examination of Water and Wastewater," 13th Edition, American Public Health Association, Washington, D.C., 1971) were followed. The chloride analysis was carried out by potentiometric titration with $AgNO_3$ of aliquots of a solution obtained by extracting 3 g of wet sludge with 100 ml of water in a soxlet extractor. Results are given in Table A-5. The nitrogen distribution is given in Table A-6.

3. Chemical Reactions of the Sludge

A major area of concern is the nature and quantity of constituents of the sludge that may be leached by rainwater or groundwater. Following suggestions of the Department of Environmental Protection of Maine (see Application for Approval of Municipal Treatment Plant Sludge Disposal Sites), we determined "water soluble cations" by extracting 50 g of wet sludge with 500 ml of distilled water for 16 hrs (with stirring). At the

Table A-4

Analyses of Metal Content of Sludge(1)

	Milligrams per Kilogram (or ppm) of Dry Weight		
	10/06/76 Grab Sample	10/27/76 Composite Sample	10/28/76 Composite Sample
Arsenic	-	-	6.8
Calcium	57,200	47,000	45,700
Cadmium	1	4	0
Chromium	73,400	71,400	73,400
Copper	121	171	128
Iron	2,690	2,600	2,690
Lead	338	488	518
Magnesium	1,870	1,670	1,643
Manganese	155	127	122
Mercury	-	-	0.65
Nickel	19	12	17
Potassium	611	370	366
Sodium	10,120	9,480	10,200
Zinc	152	134	154

---

(1) By atomic absorption using a Perkin-Elmer 560 spectrophotometer with flameless attachment.

Table A-5

South Paris Treatment Facility
Sludge Analysis Summary

	10/27/76 Composite	10/28/76 Composite	10/6/76 Grab Sample
pH(1)	7.5-8.0	7.5-8.0	7.5-8.0
% Solids (105-110°C) (dry weight)	13.8	14.1	12.0
Nonvolatile Solids (600°C) (% dry weight)	-	33.1	35.5
Total Nitrogen (% dry weight)	4.2	3.1	-
Total Chloride (% dry weight)	2.0	2.0	-
Total Phosphorous	<<0.15	<<0.15	-

---

(1) Wet sludge mixed with doubly distilled water at 25°C.

Table A-6

Nitrogen Distribution in Sludge

	Milligrams per Kilogram of Wet Weight(1)
Ammonia Nitrogen (N)	1,480
Kjeldhal Nitrogen (N)	2,460
Nitrate Nitrogen (N)	8.6
Nitrite Nitrogen	1.3

---

(1) Composite sludge of 6/22/77 with dry solids content of 13.2 ± 2%.

end of this time, aliquots of the suspension were filtered through a 0.45 micron membrane filter and the filtrate analyzed for heavy metals. Results are shown in Table A-7. As can be seen from the table, some chromium and zinc were dissolved by this procedure. Since chromium is a potentially hazardous constituent, further characterization of its tendency to dissolve from the sludge was carried out.

Since it is likely that the amount and rate of extraction of heavy metals are sensitive functions of pH, the buffering capacities of wet and dry sludge were determined by titration with dilute acid of a suspension of 0.5 g of the sludge (on a dry weight basis) in 25 cc of distilled H_2O. Results, given in Figures A-1 and A-2, show that there is little buffering capacity at pH's above 7, but there is some buffering capacity about pH 5.5. There is no significant difference between dilute HCl, HNO_3 or H_2SO_4 as the titrating acids. There is, however, a significant difference between wet and dry sludge - the latter having significantly less buffering capacity at high pH's. It is probable that drying at 105-110°C volatilizes amines and thereby decreases the basicity of the sludge. Such loss of basic capacity may also occur after drying at room temperature (except that the time interval for drying at room temperature would be much longer).

Extraction of chromium from wet sludge was studied in some greater detail. Sludge samples were suspended in distilled water and the pH adjusted to a desired value within 6 to 8 by addition of dilute HCl. After equilibration, the amount of Cr in solution was determined by filtering the suspension through a 0.45 micron membrane filter and analyzing the filtrate by atomic absorption. The relative amounts of sludge and water and the equilibration time (2 hrs to 3 days) had little influence on the amount of chromium found in solution. The determining factor was the pH of the suspension: progressively larger amounts of chromium are found

Table A-7

Water Soluble Cations Extractable from Sludge(1) Composite Sludge Sample of 10/27/76

	Concentration in Filtrate, ppm	
	Run 1	Run 2
Chromium	0.02	0.06
Cadmium	<0.01	<0.01
Copper	<0.01	0.01
Lead	<0.2	<0.2
Nickel	<0.01	<0.01
Zinc	0.01	0.02

---

(1) Fifty grams of wet sludge extracted with 500 ml distilled water for 16 hrs at room temperature. Suspensions were filtered through a 0.45 micron membrane filter and filtrate analyzed by atomic absorption.

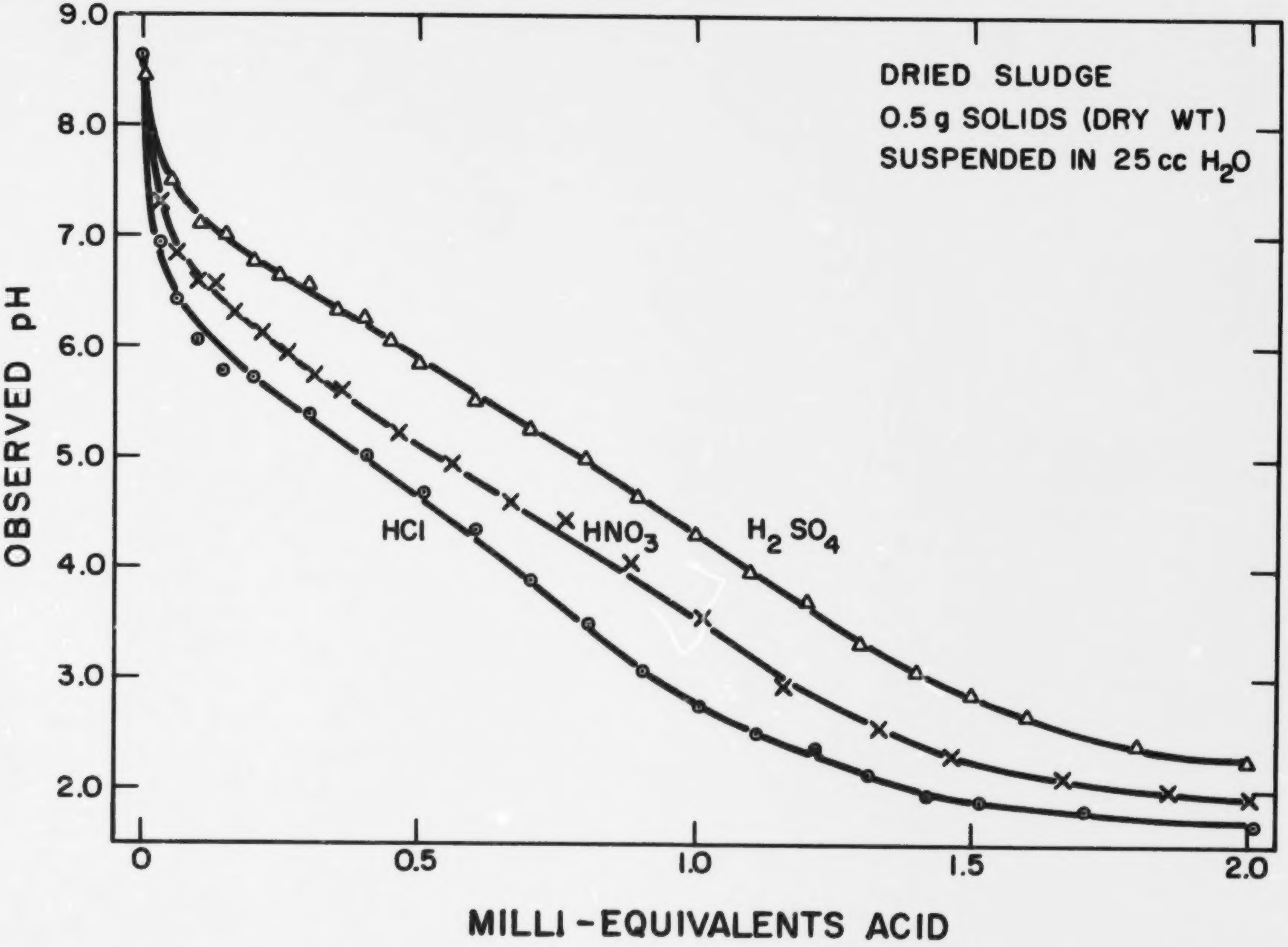

Fig. A-1: Titration curve for a suspension of dried sludge in water (0.5g solids dry weight in 25 cc of water).

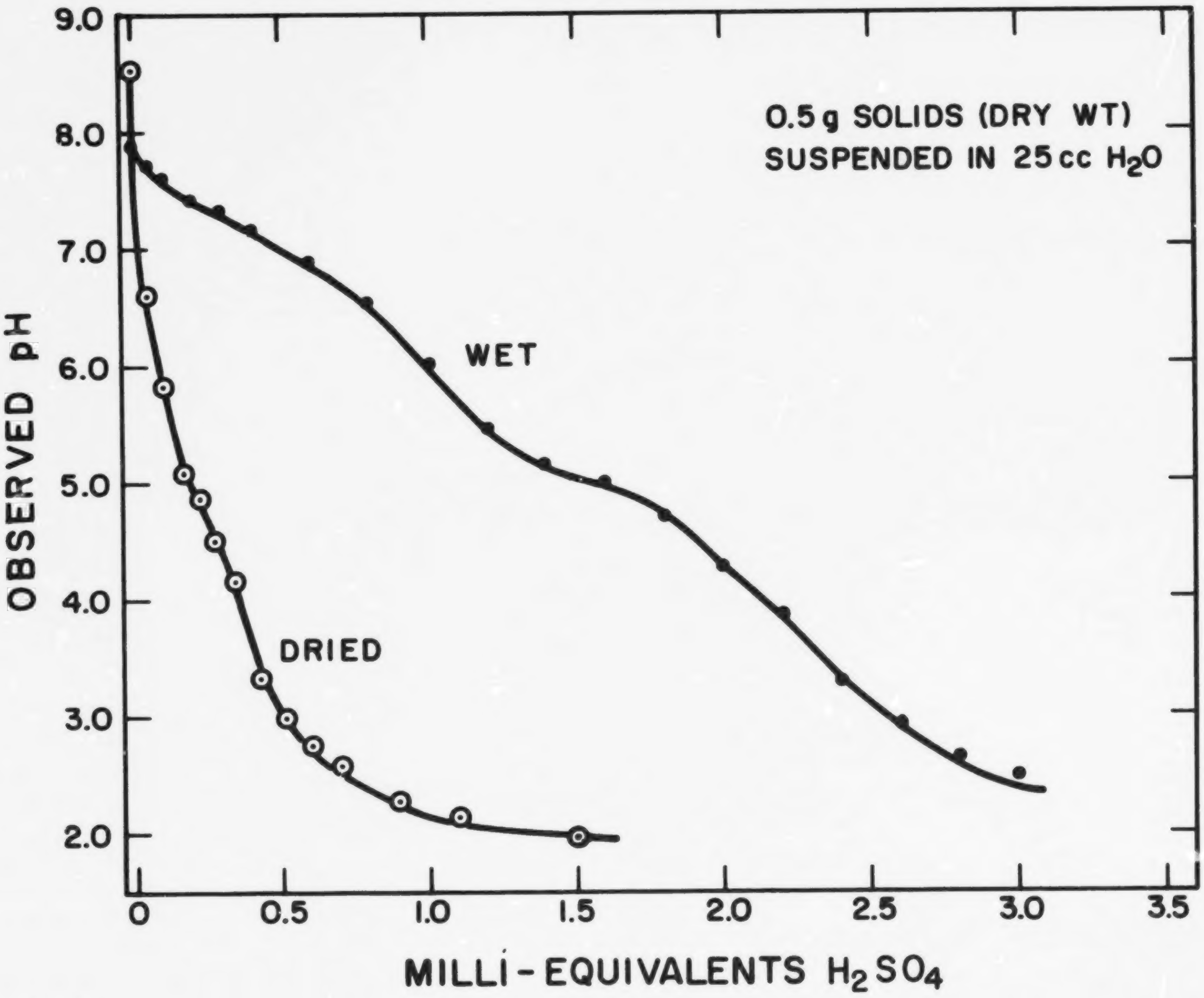

Fig. A-2: Titration curve for a suspension of sludge in water (0.5g solids of dry weight in 25 cc of water).

in solution as the pH is lowered from 8.0 to 6.25. Results are given in Table A-8.

A series of extractions were also carried out with solutions containing 500 ppm and 2000 ppm of $(NH)_4)_2SO_4$. Again, the pH of the suspension was the determining factor for the amount of chromium in solution. These results are also given in Table A-8.

4. Summary

The sludge contains approximately 14% solids, the balance being water. Of the solids, about 35% are non-volatile, the remainder being volatilized at 600°C. Of the non-volatile solids, about 90% are chromium and calcium compounds and the remainder is accounted for by iron, magnesium and sodium salts.

Trace elements in the sludge include about 150 ppm Cu, 400 ppm Pb, 150 ppm Mn and 150 ppm Zn, all on a dry weight basis. Total nitrogen is about 3 to 4%. Sulfide content is about 125 ppm and chloride is 2000 ppm. The total phosphorous content is negligible.

The amount of chromium extracted from the sludge depends strongly on the pH of the extracting solution. At pH's 7 to 8, the concentration of dissolved chromium is less than 50 parts per billion. At a pH of 6, about 200 parts per billion (0.2 ppm) are found in solution.

The buffering capacity of the sludge is slight above a pH of 6.0. There is some buffering capacity of wet sludge at pH's around 5, but it diminishes significantly upon drying.

Table A-8

Dissolved Chromium Extractable from Sludge[1]

A. Water Soluble

pH	Temp (°C)	Dissolved Cr (ppm)
6.25	25	0.21
6.75	25	0.08
7.25	25	0.04
8.00	25	0.02

B. "Rain" Soluble

1. 500 ppm $(NH_4)_2SO_4$

pH	Temp (°C)	Dissolved Cr (ppm)
5.94	25	0.60
6.51	25	0.35
6.70	35	0.23

2. 2,000 ppm $(NH_4)_2SO_4$

pH	Temp (°C)	Dissolved Cr (ppm)
7.85	25	0.03
7.85	35	<0.01

---

(1) Nominal ratios of sludge to solution were 10g of wet sludge in 100 ml of distilled water or $(NH_4)_2SO_4$ solution.

APPENDIX B

CHROMIUM CHEMISTRY AND TOXICITY

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APPENDIX B

CHROMIUM CHEMISTRY AND TOXICITY

1. Chromium Chemistry

The chemistry of chromium for all practical cases is the chemistry of its three common oxidation states, Cr(0), Cr(III) and Cr(VI). The metal, Cr(0), is resistant to oxidation because of the formation of a superficial oxide which is highly stable, except at high temperatures where appreciable bulk oxidation occurs. The environmental and health chemistry of chromium concerns therefore reactions and biological effects of Cr(III) and Cr(VI).

(a) Cr(III) Chemistry

The chemistry of the Cr(III) state is dominated by the well-defined octahedral coordination of this valence of chromium (1). Its solution chemistry is almost exclusively coordination chemistry. The number of possible complexes is enormous since any compound capable of acting as a Lewis base is potentially a complexing agent for Cr(III).

The simple hydrated ion exists at room temperature in solutions of some anions (nitrate, perchlorate), but if sulfate or chloride are present, they enter the complex with displacement of water. Complexes are formed with organic acids (formic, acetic, oxalic and the hydroxy acids) and are sufficiently stable to hinder or prevent the precipitation of Cr(III) as hydrous oxide by alkalies. Other organic ligands which combine the functions of a monobasic acid and a bidendate ligand (e.g., acetylacetone) give extremely stable complexes which are insoluble in water and can be melted and distilled at atmospheric pressure without decomposition. Such complexes are generally soluble in organic solvents.

Basic ions of chromium (e.g., $Cr(OH)(H_2O)_5^{++}$) polymerize upon standing with the formation of -OH or -O bridges. These processes (olation and oxolation) lead to precipitation of hydrous oxide which loses water upon standing or at elevated temperatures, to yield a less hydrated material (or anhydrous upon ignition).

Freshly precipitated hydrous chromic oxide redissolves in excess alkali. The simple aquo-complex is acidic (pK ~ 4) and the polynuclear complexes of "chromium hydroxide" are also acidic, but with considerably greater pK values.

The solubility product of $Cr(OH)_3$ at room temperature is generally given as $K_{sp} = 6 \times 10^{-31}$. The concentrations of various species in solution are given as functions of pH in Table B-1 and the total amount of dissolved chromium is shown as a function of pH in Figure B-1. The minimum amount of dissolved chromium in equilibrium with solid $Cr(OH)_3$ occurs at a pH of about 8 and is about 6×10^{-7}M (i.e., about 0.03 ppm as Cr).

Oxidation of Cr(III) to Cr(VI) in aqueous solution can be affected with such oxidants as hypochlorite, peroxide, and oxygen or air. Cr(III) is more difficult to oxidize in acid solutions; such oxidations require strong oxidizing agents, for example, perchloric acid or lead dioxide. The thermodynamic relations among the various oxidation states of chromium are depicted over the whole range of oxidation potentials and pH values in Figure B-2.

(b) Cr(VI) Chemistry

The other commonly encountered oxidation state of chromium, Cr(VI), includes chromic acid and various chromate salts. Chromic acid is a fairly strong, dibasic acid (first dissociation constant about 2×10^{-1}; second dissociation constant 3×10^{-7}). At high concentrations of chromate and low pH, the dichromate ($Cr_2O_7^{=}$) is formed. Chromates and dischromates are strong oxidants, particularly in acid solutions.

Table B-1

Solubility Relations of $Cr(OH)_3$ (Ref. 2)

Equilibria and Equilibrium Constants

$$Cr(OH)_3 \rightleftarrows Cr^{+3} + 3OH^- \qquad K_{so}$$

$$Cr^{3+} + H_2O \rightleftarrows CrOH^{2+} + H^+ \qquad K_1$$

$$CrOH^{2+} + H_2O \rightleftarrows Cr(OH)_2{}^+ + H^+ \qquad K_2$$

$$Cr(OH)_3 + OH^- \rightleftarrows Cr(OH)_4{}^- \qquad K_3$$

where

$$K_{so} = [Cr^{3+}][OH^-]^3$$

$$K_1 = [CrOH^{2+}][H^+]/[Cr^{3+}]$$

$$K_2 = [Cr(OH)_2{}^+][H^+]/[CrOH^{2+}]$$

$$K_3 = [Cr(OH)_4{}^-]/[OH^-]$$

Values of K_{so} range from log K_{so} = -29.8 to -30.7 at 25°C
Values of K_1 range from log K_1 = -3.80 to -4.40 at 25°C
Values of K_2 range from log K_2 = -6.22 to -6.60 at 25°C
Values of K_3 range from log K_3 = -0.4 to -1.20 at 25°C

The amount of dissolved Cr(III) at any given pH is the sum

$$\text{Total Cr(III) in solution} = [Cr^{3+}]+[CrOH^{2+}]+[Cr(OH)_2{}^+]+[Cr(OH)_4{}^-]$$

Figure B-1 was calculated with the following choices of equilibrium constants:

$$K_{so} = 10^{-30};\ K_1 = 10^{-4};\ K_2 = 10^{-6.30};\ K_3 = 10^{-1}$$

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B-4

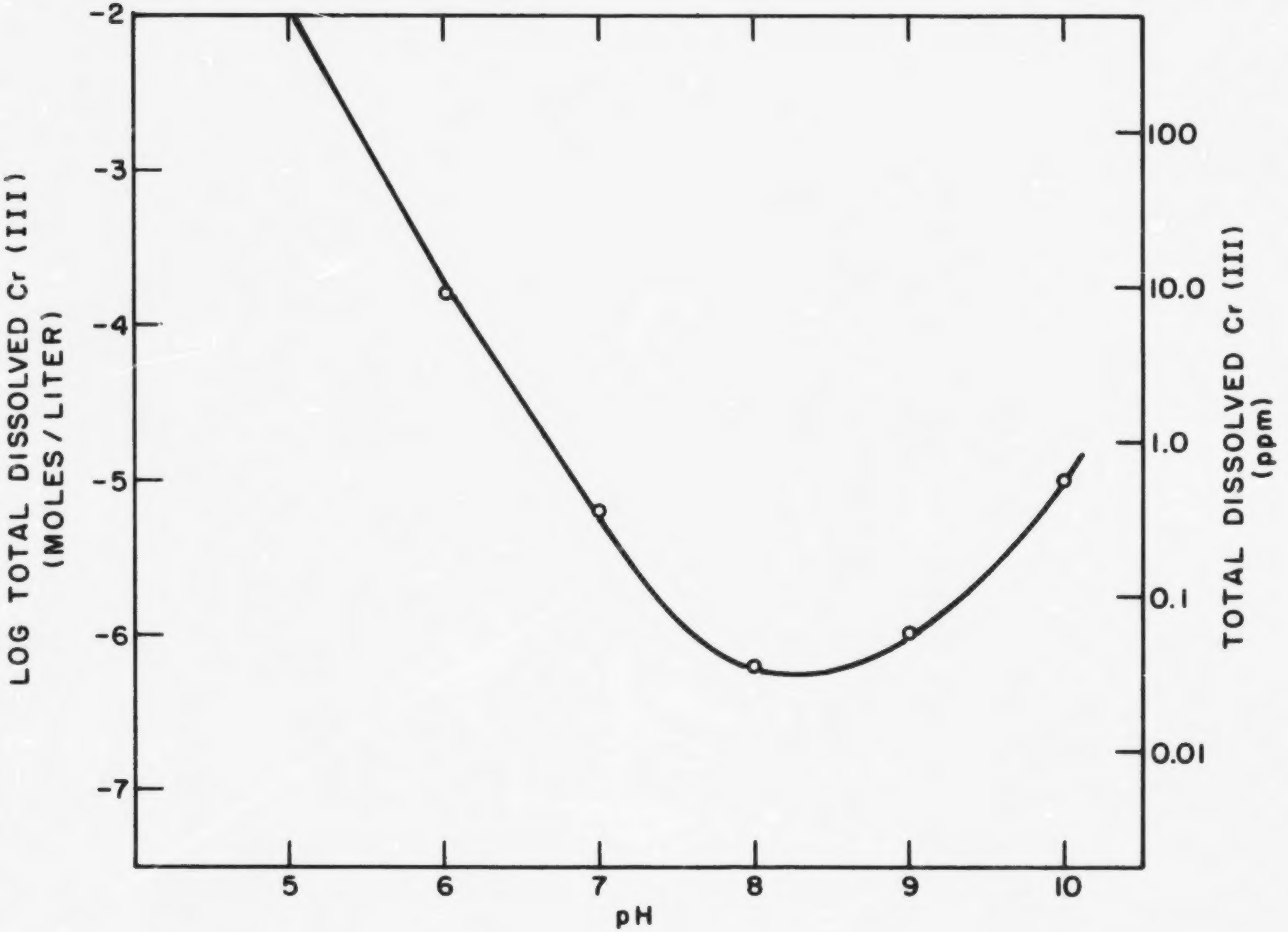

Fig. B-1: Dissolved Cr(III) in equilibrium with $Cr(OH)_3$.

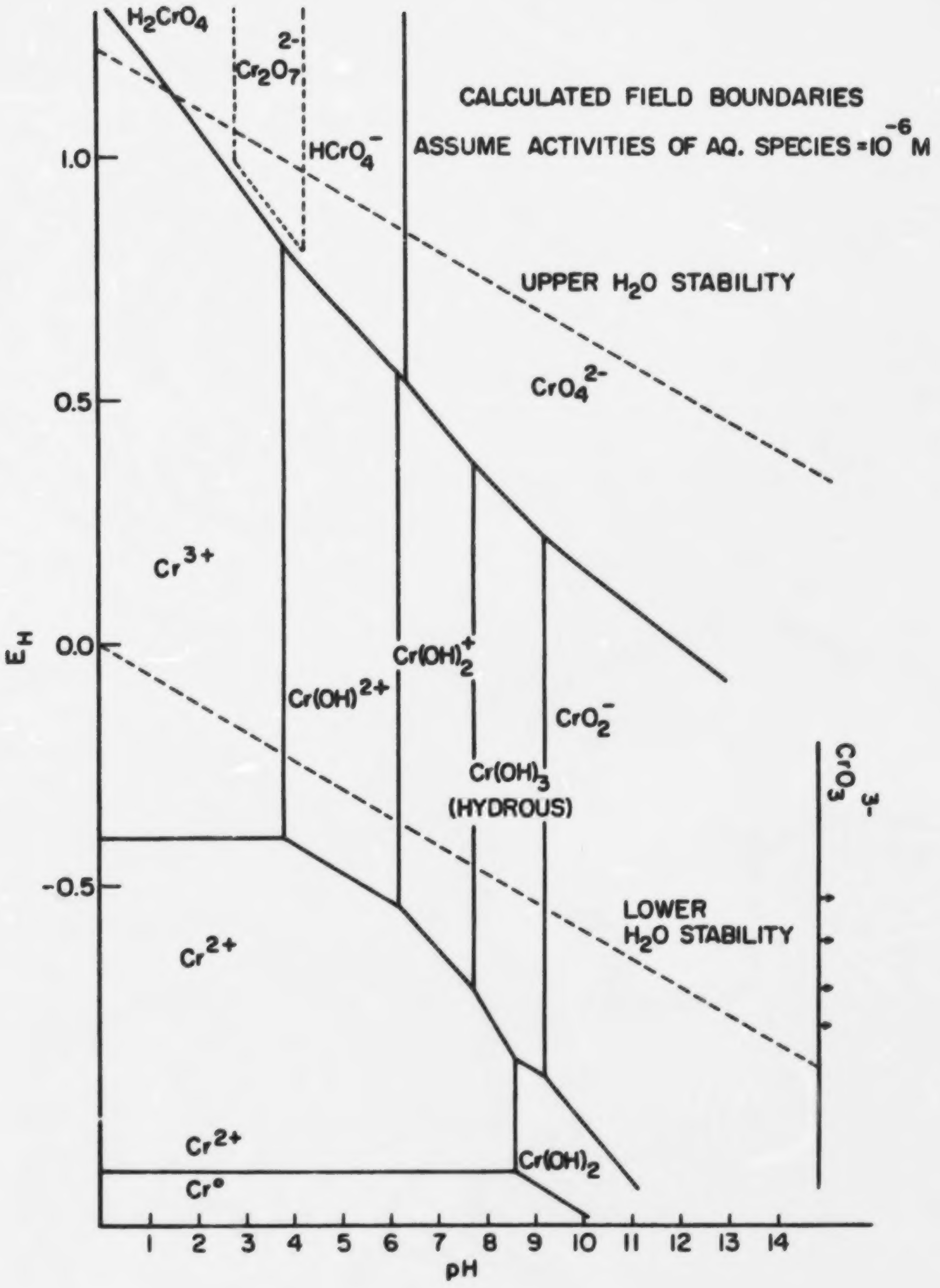

Fig. B-2: Equilibrium E_H-pH diagram for chromium.

Since Cr(VI) compounds in aqueous solutions are almost entirely in the form of oxyanions, they do not complex appreciably. They are generally reactive towards organic matter, and are thereby reduced to the Cr(III) state. However, if the concentration of oxidizable substances is low, Cr(VI) may persist in a natural aqueous environment for long periods of time.

(c) Redox Reactions and Exchange Between Cr(III) and Cr(VI)

Oxidation of Cr(III) to Cr(VI) involves an overall change of 3 units in oxidation state and is relatively slow (3,4). It appears to proceed by a succession of 1-equivalent steps, the slow step probably corresponding to the Cr(IV)-Cr(V) change. The slowness of this reaction may be associated with a change of coordination number from 6 in Cr(IV) to 4 in Cr(V) (Ref. 3,4).

Air oxidation of Cr(III) to Cr(VI) is strongly favored thermodynamically at all but the most acidic pH values. However, the kinetics are expected to be slow, although no extensive studies of the mechanism of this reaction have been reported.

A study of oxidation of Cr(III) by dissolved O_2 (4) showed that the rate was slow (3% in 30 days) with a high activation energy (∿22 kcal/mol). The rate was not sensitive to pH (6 to 10) and was unaffected by sand, bentonite, or $Fe(OH)_3$ (4). Catalysis by a uniform suspension of MnO_2 was noted in the laboratory, but not in natural waters where apparently its effect is suppressed by cations (Ca^{++}, Mg^{++}) or other inhibitors.

The slowness of reactions involving oxidation of Cr(III) to Cr(VI) is in agreement with observations on the rate of exchange between Cr(III) and Cr(VI). Elevated temperatures (∿100°C), high concentrations and extended reaction times are required to establish isotopic equilibrium (5). The rate expressions suggest that the rate-determining step involves exchange between Cr(V) and Cr(IV), the exchange between the pairs Cr(VI)-Cr(V) and Cr(IV)-Cr(III) being relatively rapid.

Oxidation rates of Cr(III) in solution may also depend on aging of Cr(III) in neutral or alkaline solutions (6). The detailed nature of changes of Cr(III) are not known, but it is fairly certain that Cr(III) polymerizes by forming hydroxy- and oxy-bridges. Such polymerization reduces significantly the reactivity of Cr(III).

The photochemistry of Cr(III) complexes (7) generally consists of substitution or substitution related reactions uncomplicated by redox processes, except for wavelengths in the UV (254 mμ or shorter wavelengths).

2. Biological Effects of Chromium Compounds

The environmental effects of chromium have recently been reviewed in detail by the U.S. National Academy of Sciences in 1974 (8) and by the National Research Council of Canada in 1976 (9). The present report is based on these reviews, supplemented by recently published papers. Aspects of chromium chemistry and toxicity particularly relevant to the situation in South Paris are emphasized.

Chromium compounds are widely distributed in the environment, and their presence is not solely a result of human activity. Chromium is an essential trace element for many species, including man. However, in unpolluted environments the level of Cr is quite low, typically less than 10 ppb (0.01 ppm) in streams and rivers. Soils and rocks contain far more Cr, from 1 ppm to over 1000 ppm, but little of this is leached into water supplies. Plants do not appear to accumulate Cr, but vegetables and fruits invariably contain Cr, typically 0.05 to 0.35 ppm. Foodstuffs are probably the major source of Cr in the human diet.

There is substantial agreement that Cr(III) salts, taken orally, have no adverse effects, even at high concentrations. For example, rats have been fed diets containing 2-5% Cr_2O_3 without any observed adverse effects (10). Furthermore, Cr(III) salts have no mutagenic activity on bacteria (11). On the other hand, Cr(III) concentrations as low as 3 ppm have been observed to be toxic to freshwater fish (9). In general, Cr(III) does not pass readily through biological membranes, which may account for its lack of activity. In fish and other aquatic organisms, however, Cr(III) may interfere with respiration (e.g., through the gills), perhaps because these membranes are more permeable.

Salts of Cr(VI) are toxic and carcinogenic. In humans, the lethal level of ingested chromate salts has been variously reported as 0.5-1.0 gram (12) to 5.0-10.0 grams (13). Individuals have been known to survive doses as high as 15 grams chromic acid (14,15), although hospitalization for 1-2 months was required, and the patients apparently were close to death. As little as 10 ppm Cr(VI) in drinking water can cause nausea or vomiting (9), but there is a report that a family drank well water containing 1-25 ppm Cr(VI) for 3 years without any observed adverse effects (16). Ingestion of only one or two glasses of water containing 420 ppm Cr(VI) caused vomiting in the case of 11 accidentally poisoned young men (17), but all recovered the next day. Drinking water containing ca. 3 ppm does not appear to cause nausea (9).

Chromate salts (Cr(VI)) show mutagenic activity in bacteria, and occupational exposure to chromates leads to an increase in lung, nasal, and other forms of cancer. Inhaling chromate mists appears to be particularly hazardous, although lethal quantities can also be absorbed through the skin.

It is well known that chromate salts are an irritant to the skin, although sensitivity varies widely. For example, some people are sensitive to chromium-tanned products (e.g., shoes) (18), and Cr in detergents and cement is often responsible for skin allergies (19). In sensitive individuals, Cr(III) also causes allergic reactions, but generally only at very high concentrations.

In 1962, the U.S. Public Health Service set the maximum level of Cr(VI) in drinking water at 0.05 ppm (20); no level was set for Cr(III).

More recently (21), the EPA (National Interim Primary Drinking Water Regulations, 1975) has set the maximum level at 0.05 ppm regardless of oxidation state. This change takes into account the possibility that Cr(III) may be oxidized by air to Cr(VI).

REFERENCES - APPENDIX B

1. For a general review of the chemistry of Cr and its compounds see "Chromium, Molybdenum and Tungsten," in *Comprehensive Inorganic Chemistry*, Vol. III by C. L. Rollinson, pp. 623-698, eds. J. C. Bailar, H. J. Emeleus, R. Nyholm and A. F. Trotman-Dickenson, Pergamon Press, 1972.
2. "Stability Constants of Metal-Ion Complexes," Compiled by L. Gunnar Sillen, Chemical Society, Special Publication No. 17, London, 1964.
3. J. H. Espenson and E. L. King, J. Am. Chem. Soc. *85*, 3328 (1963); J. H. Espenson, *ibid*., *86*, 5101 (1964); J. C. Sullivan, *ibid*., *87*, 1495 (1965); G. P. Haight, Jr., E. Perchonok, F. Emmenegger and G. Gordon, J. Am. Chem. Soc. *87*, 3835 (1965).
4. D. C. Schroeder and G. F. Lee, Water, Air and Soil Pollution, *4*, 355 (1975).
5. C. Altman and E. L. King, J. Am. Chem. Soc. *83*, 2825 (1961).
6. M. R. Baloga and J. E. Earley, J. Am. Chem. Soc. *83*, 4906 (1961).
7. A. W. Adamson, W. L. Wartz, E. Zinato, D. W. Watts, P. D. Fleischauer and R. D. Lindholm, Chem. Rev. *68*, 541 (1968).
8. _____, *Chromium*, U.S. National Academy of Sciences, Committee on Biological Effects of Atmospheric Pollutants, Division of Medical Sciences, National Research Council, Washington, D.C. (1974).
9. _____, *Effects of Chromium in the Canadian Environment*, National Research Council of Canada, Associate Committee on Scientific Criteria for Environmental Quality, Subcommittee on Heavy Metals and Certain Other Compounds, NRCC No. 15017, Ottawa (1976).
10. S. Ivankovic and R. Preussman, Food Cosmet. Toxicol. *13*, 347 (1975).
11. L. S. Levy and S. Venitt, Brit. J. Cancer *32*, 254 (1975); S. Venitt and L. S. Levy, Nature *250*, 493 (1974).
12. D. B. Kaufman *et al*., Amer. J. Dis. Child. *119*, 374 (1970).
13. C. Jelenko III, J. Trauma *14*, 65 (1974).
14. M. Goldman and R. H. Karotkin, Am. J. Med. Sci. *189*, 400 (1935).

15. B. Fristedt et al., Acta Med. Scand. 177, 153 (1965).

16. A. D. Little, Inc. (for EPA), Water Quality Criteria Data Book, Vol. 2: Inorganic Chemical Pollution of Fresh Water, U.S. Government Printing Office (1971).

17. I. J. Tartakoco, Am. J. Pub. Health 59, 1674 (1969).

18. W. Pritikin, New Eng. J. Med. 286(4), 219 (1972).

19. Anon., "Cutaneous Reactions to Chromium," Food Cosmet. Toxicol. 11, 506 (1973).

20. Federal Register, March 6, 1972, pp. 2152-2155.

21. Federal Register 40, No. 248, December 24, 1975, pp. 59566-595-88.

APPENDIX C

ANALYSIS OF THE A. C. LAWRENCE DISPOSAL SITE

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APPENDIX C

ANALYSIS OF THE A. C. LAWRENCE DISPOSAL SITE

1. Introduction

The A. C. Lawrence site, presently used to dispose sludge from the wastewater treatment plant, comprises some fifty acres situatated approximately one mile from the plant between Oxford Road and the Little Androscoggin River (see main text). Sludge from the tannery has been deposited within this area approximately over the last 20 years, generally by surface dumping. Sludge from the wastewater plant has been deposited in trenches on the western end of the site over the last year.

The Lawrence site was studied in some detail to determine whether its use over the last 20 years has led to groundwater contamination and, if so, what corrective and monitoring measures should be taken. Its suitability for continued use and expansion was also ascertained in the course of this work.

2. Geology of the A. C. Lawrence Site

(a) Regional Geology

Approximately 14,000 years ago a large mass of continental glacial ice began to disintegrate over the northeastern United States. In the area of the Little Androscoggin River Valley, the advancing ice apparently removed very little material, but it did deposit a discontinuous layer of glacial till over the bedrock hills of the area. As the ice melted down sufficiently to expose the topographically high bedrock and till areas, meltwater streams deposited sand and gravel along the ice margin and in tunnels beneath the ice. These stream deposits later became kame terraces and eskers. Closely following the dissipation of the glacial ice, the area of the Androscoggin and Little Androscoggin River Valleys was subjected to a marine submergence. This submergence resulted in the deposition of glaciomarine silt and sand to a present elevation of approximately 400 feet in the Androscoggin River Valley, and to a present elevation of at least 350 feet in the Little Androscoggin River Valley. No continuous marine deposits were identified during the investigation of the A. C. Lawrence sludge site, even though the four test holes located in the outwash terrace penetrated elevations at which marine deposits would be expected. This suggests that the marine water in the Little Androscoggin River Valley was blocked by ice or some other barrier from submerging the Paris area. Alternatively, the very thin silt and fine sand layers that locally overlie the till at the present site and the outwash deposits to the north and east, may represent the inland estuarine sediments associated with the late-glacial marine invasion. The absence of these fine grained marine deposits in the Paris area indicates that a major ground water controlling horizon is lacking and thus ground water is free to move throughout the glaciofluvial valley fill sediments.

During the late stages and immediately following the period of marine deposition, glaciofluvial sands were transported and deposited down valley by glacial melt water streams. These glaciofluvial outwash sands were deposited to thicknesses well in excess of one hundred feet. As the marine waters receded to present sea level, these glaciofluvial outwash sands were incised as streams readjusted to a lowered regional base level.

Thus, much of the geomorphology and surficial geology of the region is a result of a late Wisconsin glaciation event. The local Pleistocene geologic column includes, chronologically, till, ice contact deposits, marine lutaceous sediments, and glacial outwash and alluvium. Till directly overlies a basement complex of early Paleozoic metamorphic rocks intruded by Devonian granitic rocks. Till is frequently overlain at lower elevations by ice contact deposits, marine sediments and outwash deposits although the sequence is complete in few instances.

(b) Local Geology

The present Paris Utility District sludge disposal (A.C. Lawrence) site occupies a till ridge that is bounded on all sides by glaciofluvial valley fill sediments. As depicted on cross-section A-A' (Fig. C-2) the glaciofluvial sands east of the present site reach a thickness of approximately forty feet and overlie glacial till. This area of topographically flat glaciofluvial sand is bounded to the east by the till mantled bedrock highlands forming the eastern wall of the Little Androscoggin River Valley. The ground water table throughout this area of glaciofluvial sands slopes to the north, presumably draining around the north end of the till ridge on which the sludge site is located, and then to the river.

The five test holes that were drilled within the boundaries of the present site encountered a gravel and sand rich glacial till that reaches thicknesses of up to fifty-five feet under the western margin of the site. Under the east-central portion of the site the till thickness diminished to approximately twenty-eight feet. Two test holes drilled by the rotary method (#4, #5) revealed that the till in the area of the sludge disposal site is underlain by granitic bedrock. All five test holes drilled beneath the present site encountered no ground water.

A broad, nearly level terrace, underlain by glacial outwash sands that reach a thickness of one hundred feet, extends from the kame terrace described above to a similar kame terrace west of the Little Androscoggin River. The ground water table in the outwash occurs approximately at river level, and has a gentle gradient sloping to the south. This outwash terrace is an erosional remnant of previously much thicker outwash deposits that have been dissected by the Little Androscoggin River. The surface of this outwash plain is locally overlain by thin alluvial deposits or shows the effects of overbank deposition or flood channel incision.

(c) Drill Data

The location of test holes drilled directly at the present disposal area on the Lawrence site is shown in Fig. C-1 and the drilling logs are given in Table C-1. Using these results and data from test holes 6 through 17 (given later in Table C-7), the geology of cross section A-A' (Fig. C-5) was constructed and is shown in Fig. C-2.

(d) Augered Test Holes

Test holes were augered at locations shown in Fig. C-3. These were sampled for subsequent analyses. Table C-2 is a log of observations made in the field.

Samples obtained at various depths were characterized in terms of particle size distribution. The size analyses were generally carried out by dry sieving; three samples from hole #8 were wet sieved because of their apparent abundant fine-fraction containing clay minerals. The sieve analysis was carried out using the following sieves: 5 mesh (4 mm), 10 mesh (2 mm), 20 mesh (0.84 mm), 80 mesh (0.18 mm) and 200 mesh (0.074 mm); and a bottom pair.

The dry-sieved samples were carefully split after passage through the 10 mesh screens to reduce the sample mass to a level most efficiently handled by the finer-mesh screens. The weights determined for the finer mesh fractions were adjusted to the original sample mass.

Organic matter in the samples was not removed; accordingly, each fraction contains some organic material. In the dry-sieved samples, the organic content was low and is probably insignificant. In the wet-sieved samples (test hole #8), there was an appreciable amount of organic debris.

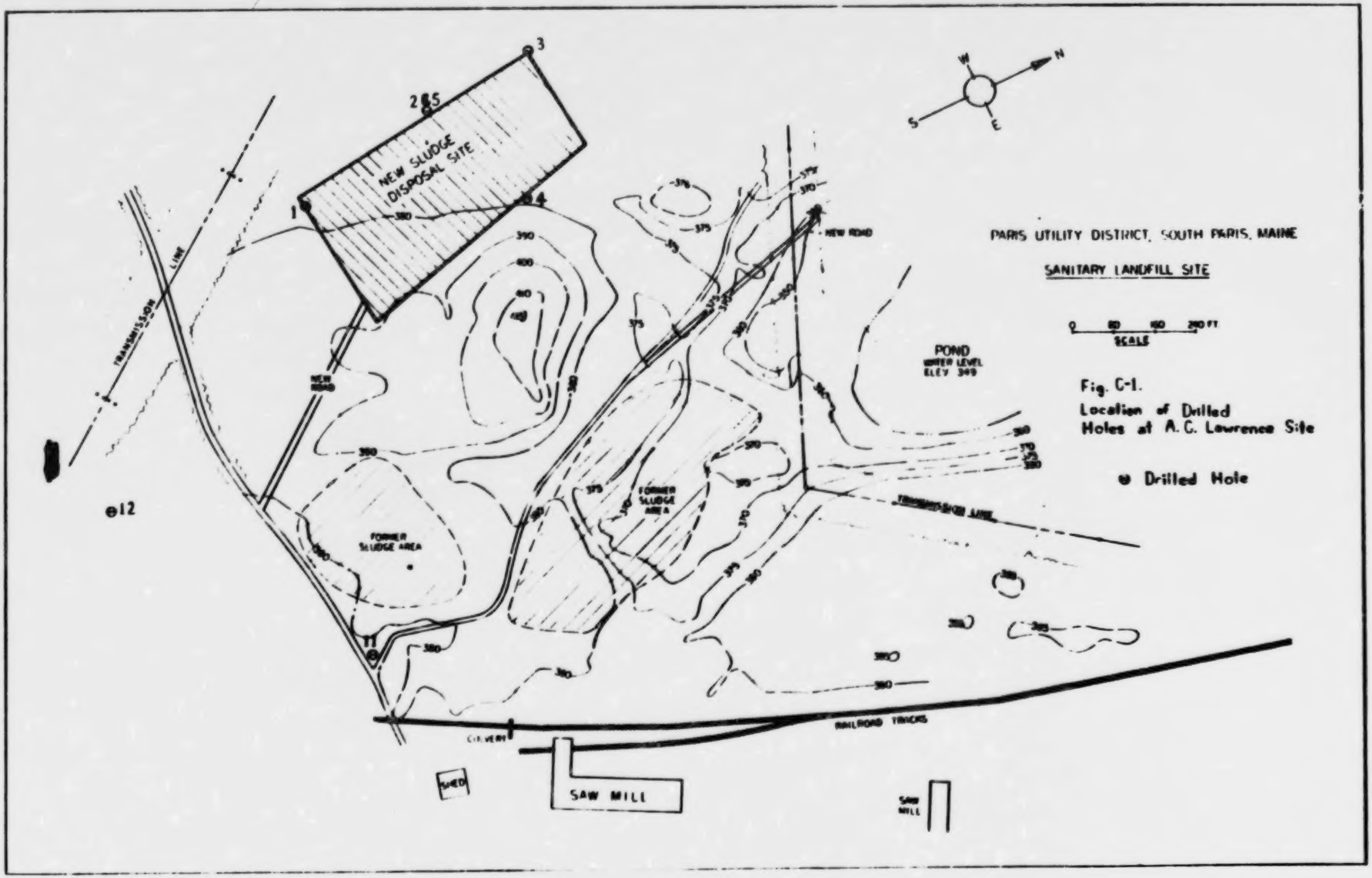
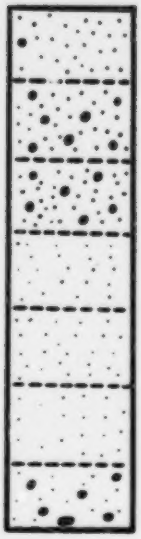

PARIS UTILITY DISTRICT, SOUTH PARIS, MAINE
SANITARY LANDFILL SITE
0 80 160 240 FT
SCALE
Fig. C-1.
Location of Drilled
Holes at A.C. Lawrence Site
Drilled Hole
N
S
W
E
NEW SLUDGE DISPOSAL SITE
1
2&5
3
4
12
11
NEW ROAD
TRANSMISSION LINE
FORMER SLUDGE AREA
POND
WATER LEVEL
ELEV 349
RAILROAD TRACKS
CULVERT
SHED
SAW MILL
380
390
400
410
375
370
360
350

Fig. C-1: Location of test holes #1-#5 at the A. C. Lawrence site.

Table C-1

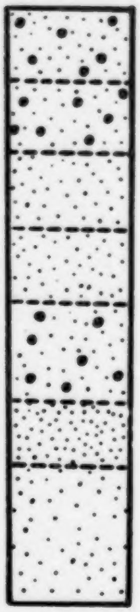
Test Hole Descriptions, A.C. Lawrence Site, South Paris

Test Hole #1



0'-5'	Fine to coarse grained, moderately compact, brown sand.
5'-10'	Medium to coarse grained, gravelly, brown sand.
10'-15'	Fine to coarse grained, gravelly, compact, reddish brown sand.
15'-20'	Fine grained, uniform, very compact, reddish brown sand.
20'-25'	Very fine to fine grained, clayey, uniform, very compact, reddish brown sand.
25'-38'	Fine grained, silty, uniform, reddish brown sand.
38'-45'	Medium grained, gravelly, uniform, very compact, brown sand.
45'	Refusal.

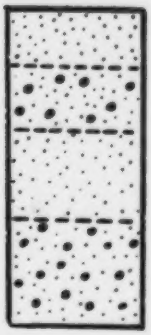
Test Hole #2



0'-5'	Medium to coarse grained, gravelly, reddish brown sand.
5'-10'	Medium to coarse grained, gravelly, brown sand.
10'-15'	Medium grained, very uniform, moderately compact brown sand.
15'-20'	Medium to coarse grained, uniform, brown sand.
20'-35'	Medium to coarse grained, gravelly, very compact, brown sand.
35'-40'	Medium to coarse grained, very uniform, very compact brown sand.
40'-55.5'	Medium to coarse grained, very angular, very compact, brownish white sand.
55.5'	Refusal.

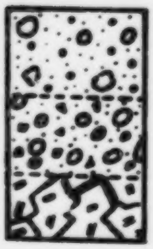
Table C-1
(Continued)

Test Hole #3



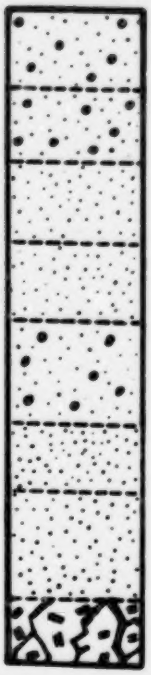
0'-5'	Medium to coarse grained, uniform, brown sand.
5'-15'	Fine to medium grained, gravelly, uniform, moderately compact, brown sand.
15'-20'	Fine grained, uniform, very compacted, brown sand.
20'-25'	Fine to coarse grained, pebbly, very compact brown sand.
25'	Refusal.

Test Hole #4



0'-18'	Coarse grained, gravelly, bouldery, very angular sand.
18'-28'	Medium to coarse grained, very sandy, bouldery, very angular, gravel.
28'-35'	Highly weathered and fractured granite.

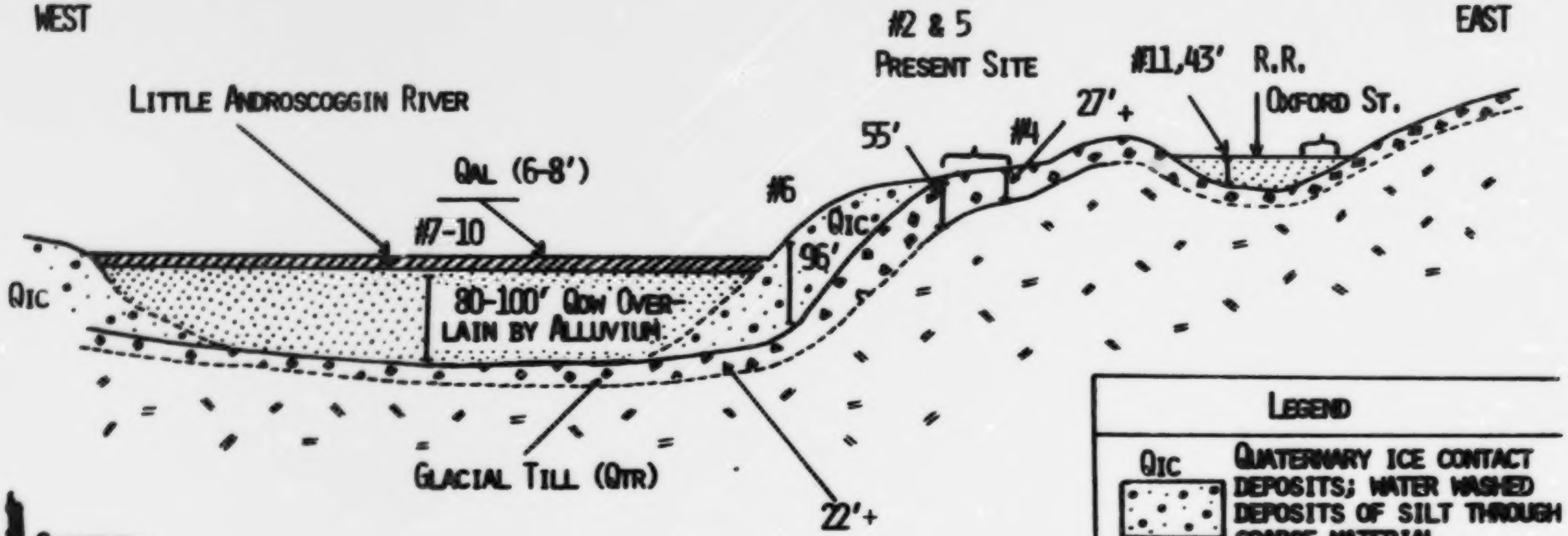
Test Hole #5



0'-5'	Medium to coarse grained, gravelly, reddish brown sand.
5'-10'	Medium to coarse grained, gravelly, brown sand.
10'-15'	Medium grained, very uniform, moderately compact, brown sand.
15'-20'	Medium to coarse grained, uniform, brown sand.
20'-35'	Medium to coarse grained, gravelly, very compact, brown sand.
35'-40'	Medium to coarse grained, very uniform, very compact brown sand.
40'-55'	Medium to coarse grained, very angular, very compact brownish white sand.
55'-65'	Highly weathered, fractured, granite.

C-8

GEOLOGIC CROSS SECTION AT PRESENT SLUDGE DISPOSAL SITE


WEST
EAST
#2 & 5
Present Site
#11,43'
R.R.
Oxford St.
Little Androscoggin River
55'
#4
27'+
Qal (6-8')
#6
Qic
96'
#7-10
Qic
80-100' Qow overlain by alluvium
Glacial Till (Qtr)
22'+

Legend	
Qic ⁘	Quaternary ice contact deposits; water washed deposits of silt through coarse material.
Qow ⁚	Quaternary outwash, well sorted; stratified sand and gravel.
Qtr ●	Quaternary glacial till, discontinuous over bedrock; varying in thickness from 0 to >22 ft.
▨	Quaternary alluvium.
⁄	Northeast and north-northeast striking Paleozoic metasediments and granitic intrusives of the New Hampshire Plutonic series.
--------	Inferred stratigraphic contacts.

Comments:

1. No continuous silt and clay deposits, which might represent marine sediments occurring down valley, were found associated with Qow (Test holes #7-10).
2. The glacial till underlying the present site and the hill east of the site is composed in large part of very compact, angular sand and gravel with local accumulations of boulders and fine material.
3. No standing groundwater was found overlying bedrock beneath present site.

Fig. C-2: Geologic cross section of A. C. Lawrence site and surroundings (along line A-A' shown in Fig. C-5).

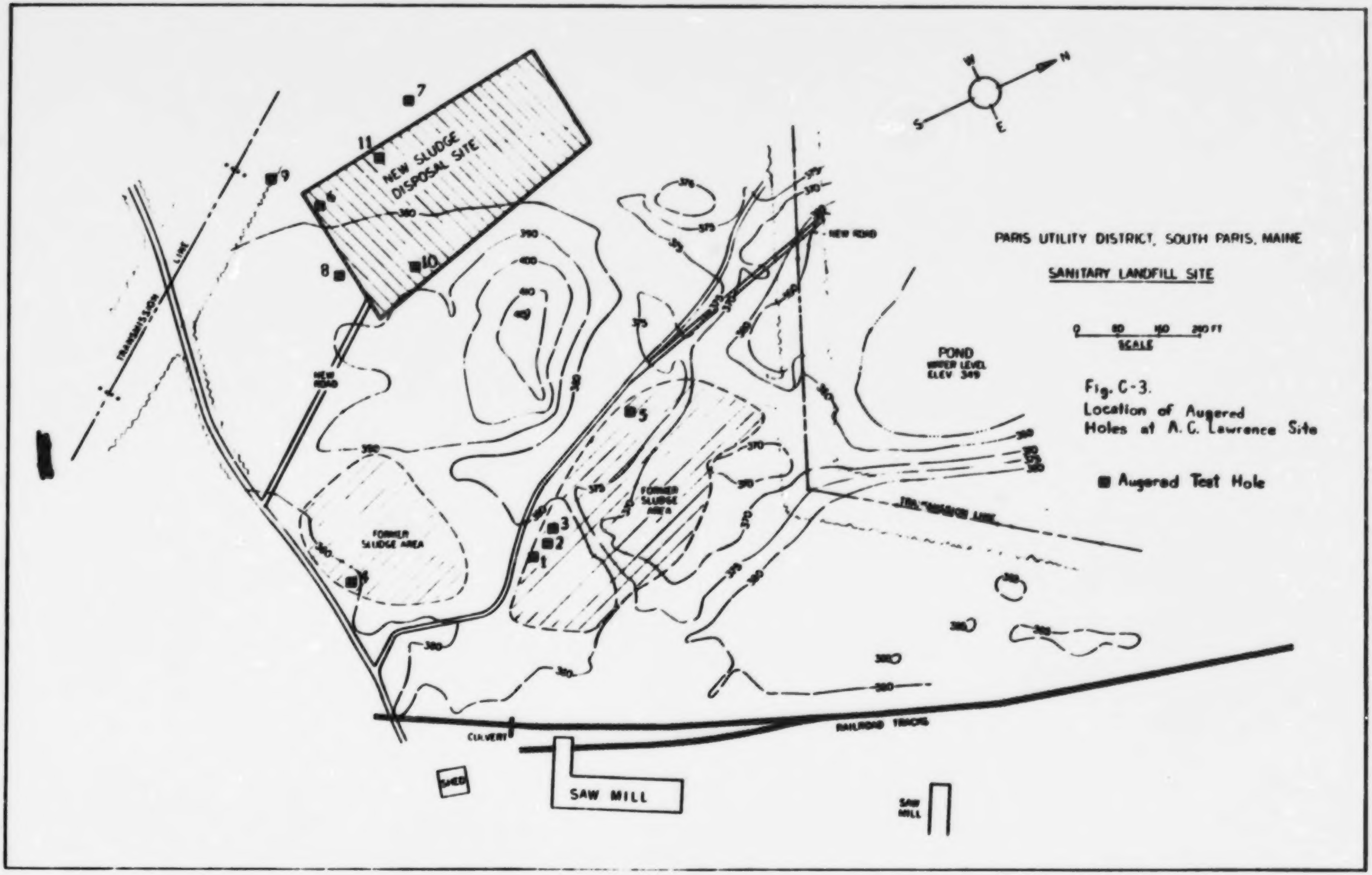

PARIS UTILITY DISTRICT, SOUTH PARIS, MAINE
SANITARY LANDFILL SITE
0 80 160 240 FT
SCALE
Fig. C-3.
Location of Augered Holes at A. C. Lawrence Site
■ Augered Test Hole
N
S
W
E
NEW SLUDGE DISPOSAL SITE
FORMER SLUDGE AREA
FORMER SLUDGE AREA
POND
WATER LEVEL ELEV 349
NEW ROAD
NEW ROAD
TRANSMISSION LINE
TRANSMISSION LINE
RAILROAD TRACKS
CULVERT
SHED
SAW MILL
SAW MILL
1
2
3
4
5
6
7
8
9
10
11
380
390
400
410
370
375
360

Fig. C-3: Location of augered test holes.

Table C-2

Description of Augered Test Holes at the A. C. Lawrence Disposal Site

October 25, 1976

Hole #1

Sample No.	Depth	Comments
1	2.5'	Coarse sand and pebbles
2	6.0'	Coarse sand with mica
3	9.0'	Medium sand with mica
4	12.0'	Coarse sand and pebbles

Hole #3

6	surface	Soil
7	2'	Sludge
8	3'	Sandy; mixed
9	4'	Sludge
10	7'	Sand
11	8.5'	Sand
12	10.0'	Sand
13	12.0'	Sand (grainy)
14	14.0'	Sand

Hole #4

20	6.0'	Topsoil, possibly mixed with sludge
21	1.0'	Grayish solid/sludge mix
22	4.0'	Coarse sand
23	7.0'	Coarse sand
24	9-1/2'	Coarse sand

Hole #5

25	surface	Sludge/topsoil mix
26	3.0'	Wet sludge
27	7-1/2'	Soil saturated with sludge leachate
28	10.0'	Gray/black sand
29	12-1/2'	Gray/black sand and sludge

Hole #6

30	4.0'	Medium/fine, lower B horizon
31	8.0'	Coarse sand and gravel

Table C-2
(Continued)

Hole #7

Sample No.	Depth	Comments
32	3-1/2'	Original topsoil
33	5-1/2'	Medium sand
34	10.0'	Medium sand
35	14-1/2'	Medium sand
36	16.0'	Medium sand
Hole #8		
37	1.0'	Topsoil
38	5.0'	Medium/fine B horizon
	at 11.0'	Wet, claylike material begins
39	12.0'	Wet clay
40	14.0'	Claylike material
Hole #9		
41	3.0'	Coarse
42	6.0'	Coarse
43	9.0'	Coarse
	gravel at ∿9'	
Hole #10		
44	3.0'	Coarse sand, some fines on bottom
45	5-1/2'	Fines, started at 3'
46	7-1/2'	Fines, clear sludge odor
47	11-1/2'	Fines, clear sludge odor
	12.0'	Very wet
48	14.0'	Very wet
Hole #11		
49	5.0'	Coarse sand/gravel
50	9.0'	Coarse sand/gravel

The data are reported (Table C-3) as fractions (percentages) greater than 20 mesh; between 20 and 80 mesh; between 80 and 200 mesh; and less than 200 mesh. The fraction (percentage) greater than 20 mesh was obtained by combining the observed fractions (percentages) for greater than 5 mesh, between 5 and 10 mesh, and between 10 and 20 mesh.

Table C-3 indicates that the site is quite heterogeneous in terms of particle size distribution. Although some samples contained a considerable amount of fines (< 200 mesh), with an average amount of about 22% for these samples, numerous samples contained very few fines ($< 0.5\%$ in many cases). A simple statement of the percentage of fines is not possible given the heterogeneity of the site.

The presence of sand members with few fines and correspondingly high permeability among the soils of the site may lead to high overall permeability in these deposits. However, angularity may keep permeability low.

(e) X-Ray Analyses of Soils and Sediments

Table C-4 presents results of X-ray diffraction analyses of soil and sediment samples from auger holes on the A.C. Lawrence site. This data was compiled from diffractograms of the $>$ 200 mesh, the $<$ 200 mesh and, in some instances, the ultra-fines removed in aqueous suspension. The results indicate a high proportion of quartz (SiO_2), alkali feldspar ($K,NaAlSi_3O_8$), sodic plagioclase feldspar ($NaAlSi_3O_{8_x}$, $CaAl_2Si_2O_{8_{1-x}}$) and a low percentage of phlogopite mica $[K(Mg,Fe)_3\ (AlSi_3O_{10})(OH)_2]$. This assemblage of minerals is consistent with the derivation of the ice contact and glacial outwash deposits from granitic basement rocks. Optical microscopy confirms the presence of these minerals as well as opaque accessories (probably magnetite). The phlogopite mica is present in the majority of samples and is readily observed visually. It is not always abundant enough to be detected by X-ray analysis (therefore, the phlogopite probably constitutes $<$ 5 percent of most samples).

Table C-3

Particle Size Distribution of Samples from Augered Holes at A. C. Lawrence Site

Augered Hole #1

	Size Distribution			
Depth (ft)	>20 Mesh (%)	>80 Mesh (%)	>200 Mesh (%)	< 200 Mesh (%)
2.5	47.9	44.6	4.1	3.4
6.0	14.4	68.2	12.8	4.6
9.0	8.4	41.1	37.8	12.8
12.0	57.2	34.2	6.4	2.2
Augered Hole #4				
4.0	50.7	48.5	0.8	0.4
7.0	35.0	63.4	1.2	0.4
Augered Hole #6				
4.0	2.4	16.5	40.2	40.8
8.0	60.2	31.3	4.9	3.6
Augered Hole #7				
2.5	9.1	47.7	18.6	24.5
5.5	4.6	85.6	9.5	0.3
10.0	3.3	73.9	21.0	1.8
14.5	4.3	71.5	21.1	3.2
16.0	4.0	80.1	14.8	1.1
Augered Hole #8				
1.0	6.5	31.6	21.2	41.6
5.0	1.4	14.8	16.9	67.0
12.0	1.1	5.3	4.4	89.3
14.0	2.5	14.4	10.5	72.6

Table C-4

Results of Mineralogical Analyses by X-Ray Diffraction

Augered Hole #1

Depth (ft)	X-Ray Analysis (Composite)				
	Quartz	Plagioclase	Feldspar	Phlogopite	Chlorite
2.5	X	X	X	X	N.D.
6.0	X	X	X	X	N.D.
9.0	X	X	-	X	N.D.
12.0	X	X	X	X	N.D.
Augered Hole #4					
4.0	X	X	?	X	N.D.
7.0	X	X	?	X	N.D.
Augered Hole #6					
4.0	X	X	-	N.D.	N.D.
8.0	X	X	X	X	N.D.
Augered Hole #7					
2.5	X	X	?	N.D.	N.D.
5.5	X	X	X	X	N.D.
10.0	X	X	?	X	N.D.
14.5	X	X	X	X	N.D.
16.0	X	X	X	X	N.D.
Augered Hole #8					
1.0	X	X	X	N.D.	N.D.
5.0	X	X	X	X	N.D.
12.0	X	X	-	X	X
14.0	X	X	X	X	X

Although these deposits are rather low in fines ($<$ 200 mesh), the deposits might have substantial cation exchange value if the fine fraction consisted largely of clay minerals. This was not the case. X-ray analyses of material $<$ 200 mesh in these samples show that the fines are largely devoid of clays and consist mainly of quartz, sodic plagioclase and alkali feldspars.

Chlorite $[(Mg,Fe,Al)_6(Al,Si)_4O_{10}(OH)_8]$ was determined by X-ray analysis of material separated from some of the samples in aqueous suspension. In these cases, the suspended fine fraction was also found to contain a large proportion of phlogopite. This is consistent with the probable derivation of the chlorite by weathering of the phlogopite which is the only primary silicate bearing Fe and Mg which are essential components of chlorite. The silt clay members found in auger holes 8 and 10 probably owe their origin to the weathering of phlogopite. However, even these beds consist mainly of non-phyllosilicates and the clay (chlorite) component of these deposits is probably less than 5 percent. These deposits are generally low in fines and simultaneously low in clays and mica.

(f) Soils

The results of a medium intensity soil survey including the A.C. Lawrence site are available from the District Soil Conservation Service. Figure C-4 shows the areal distribution of soil types at the site. Characteristics and properties of these soil types are detailed in the USDA publication, "Soil Survey - Androscoggin and Sagadahoc Counties, Maine (1970)." Descriptions of the characteristics and engineering properties of these soils are given in Table C-5. The soils have been given an unfavorable rating by the USDA for use in sanitary landfills.

Adams series soils have been described as highly drained with slopes ranging from 0 to 49 percent. These soils are typically sandy and strongly acid. They occur on terraces and eskerlike ridges and, in the southern Androscoggin County, are developed on deltaic and outwash sands.

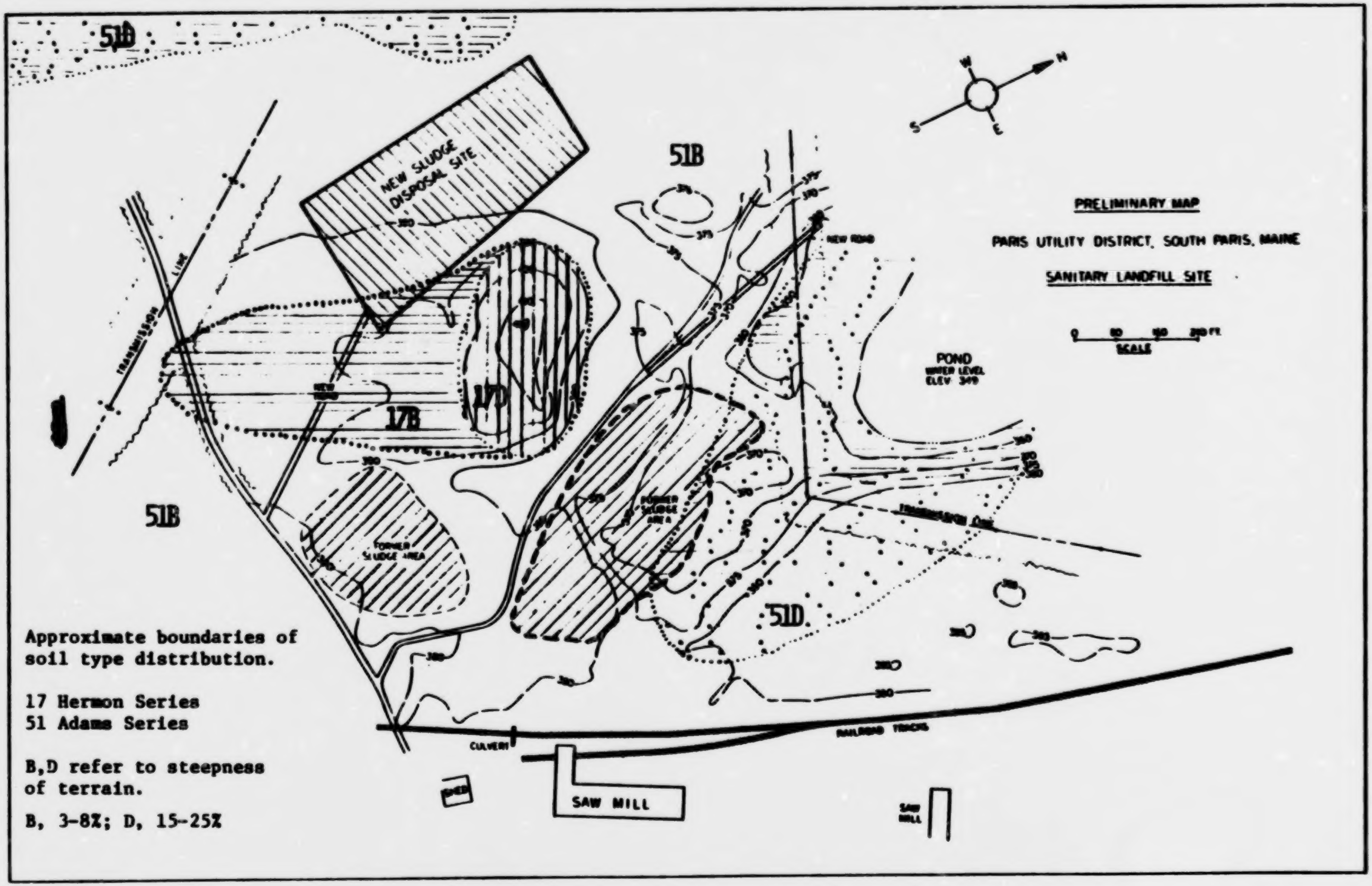

51D
51B
NEW SLUDGE DISPOSAL SITE
N
W
S
E
PRELIMINARY MAP
PARIS UTILITY DISTRICT, SOUTH PARIS, MAINE
SANITARY LANDFILL SITE
0 50 100 200 FT.
SCALE
TRANSMISSION LINE
NEW ROAD
17B
17D
POND
WATER LEVEL
ELEV. 349
FORMER SLUDGE AREA
FORMER SLUDGE AREA
51B
51D
380
375
370
CULVERT
RAILROAD TRACKS
SHED
SAW MILL
SAW MILL
Approximate boundaries of soil type distribution.
17 Hermon Series
51 Adams Series
B,D refer to steepness of terrain.
B, 3-8%; D, 15-25%

Fig. C-4: Distribution of soil types at the A. C. Lawrence site.

Table C-5

Physical Properties of Soils Occurring at the A.C. Lawrence Site

(Adapted from the USDA publication, Soil Survey - Androscoggin and Sagadahoc Counties, Maine (1970))

Soil Series/ Map Symbol	Depth from Surface	Classification USDA	AASHO
Adams, 51	0-24	Loamy Fine Sand	A-2
	24-40	Fine Sand	A-3

Percentage Passing Sieve No. 4 (4.7 mm)	No. 10 (2.0 mm)	No. 200 (0.074 mm)	Permeability (In./hr.)
100	95-100	10-30	>6.3
100	95-100	2-5	>6.3

Available Water Capacity In/in. of Soil	Shrink-Swell Potential
0.05-0.08	Low
0.02-0.06	Low

Soil Series Map Symbol	Depth from Surface	Classification USDA	AASHO
Saco, 8	0-50	Silt-Loam	A-4

Percentage Passing Sieve No. 4 (4.7 mm)	No. 10 (2.0 mm)	No. 200 (0.74 mm)	Permeability (In./hr.)
95-100	95-100	60-90	0.63-2.0

Available Water Capacity In/in. of Soil	Shrink-Swell Potential
0.18-0.28	Low

Table C-5
(Continued)

Soil Series/ Map Symbol	Depth from Surface	Classification USDA	AASHO
Ondawa, 1X	0-30	Fine Sandy Loam	A-4
	30-48	Sand	A-2

Percentage Passing Sieve			Permeability (In./hr.)
No. 4 (4.7 mm)	No. 10 (2.0 mm)	No. 200 (0.074 mm)	
95-100	95-100	45-50	2.0-6.3
95-100	70-95	15-25	2.0-6.3

Available Water Capacity In/in. of Soil	Shrink-Swell Potential
0.13-0.17	Low
0.08-0.14	Low

Soil Series Map Symbol	Depth from Surface	Classification USDA	AASHO
Hermon, 17	0-10	Sandy Loam	A-2, A-4
	10-18	Gravelly Sandy Loam	
	18-40	Gravelly to Very Gravelly Loamy Sand	

Percentage Passing Sieve			Permeability (In./hr.)
No. 4 (4.7 mm)	No. 10 (2.0 mm)	No. 200 (0.074 mm)	
70-95	65-85	20-40	2.0-6.3
50-80	40-70	15-30	2.0-6.3
45-80	40-70	0-30	2.0-6.3+

Available Water Capacity In/in. of Soil	Shrink-Swell Potential
0.05-0.15	Low
0.02-0.14	Low
0.01-0.09	Low

In typical wooded areas, Adams soils have a thin, gray to dark gray surface layer. Subsoil is dark brown or yellowish brown. Loamy sand occurs to a depth of about 24 inches. The underlying material, to a depth of about 40 inches is light brown, loose sand.

Hermon series soils have been described as sandy, well-drained, strongly-acid soils developed on coarse sandy granitic till occurring on uplands with slopes of from 3 to 60%. These soils have about 18 inches of sandy loam overlying coarse loamy sand including many coarse fragments.

Saco series soils occupy low lying areas slightly above the level of adjacent streams where they have developed on recent alluvium. These soils are nearly permanently saturated. The soil profile includes a surface layer of black silt loam to a depth of about 10 inches. This overlies a gray, silt loam to a depth of about 30 inches.

The Ondawa series includes deep and well-drained soils developed in sandy alluvium and flood plains primarily along the Androscoggin and Little Androscoggin Rivers. These soils typically have a fine sandy loam surface layer to a depth of about 8 inches. This overlies brown and gray-brown sandy loam and a deeper horizon of gray-brown sand.

3. Hydrology of the A. C. Lawrence Site

(a) Survey of Site

A number of test wells were drilled on the immediate site and in its vicinity to establish groundwater levels, flows, and water quality. In all, eighteen test holes (some of which did not show any groundwater) were drilled. The site was then surveyed to establish ground elevations at each test well.

Comparative elevations of each test-hole site were converted to sea level elevations by using the nearest USGS BM located in the foundation of the South Paris Courthouse. This bench mark was carried along the railroad tracks to the original zero control on the railroad bridge south of the road leading to the site, with a seeming error (as compared to data on the topographic map) of +0.486'. The data were not reconciled to that on the topographic map, since a point of reference could not be established except at the bridge. The massive cement blocks now surfacing it have a variation of ± 1.0' from point to point, that is, a variation greater than the discrepancy between this survey and the topographic map previously prepared.

(b) Test Hole Drilling Data

Test holes drilled during the hydrologic survey are listed in Table C-6 and shown in Fig. C-5. The groundwater elevation at each location can be used to derive the groundwater gradients. These elevations are given in Table C-6 and noted in Fig. C-5. It should also be noted that test holes #14 through #16 were drilled approximately one month later than test holes #1 through #10. During this period groundwater levels dropped approximately 1.0 ft. Therefore, the levels noted for these wells are not directly comparable with the others.

Drilling logs for test holes #1 through #5 were given previously in Table C-1. Logs for holes #6 through #16 are given in Table C-7. The drilling log for test hole #17 is given later in the section dealing with chemical analyses of soil samples taken under old sludge deposits.

(c) Pump Tests

Pump tests were carried out at wells #8, 13 and 14. Observation wells were, respectively, #9 (2 ft from well #8), #16 (3 ft from well #13) and #15 (2 ft from well #14).

In pump tests with wells #8 and #9, the screen in well #8 was set between 67.5 and 77.5 ft from ground level and the well was pumped at 15 gpm. The screen in observation well #9 was set between 65 and 75 ft.

Table C-6

Test Hole Elevations and Groundwater Elevations

(A. C. Lawrence Site and Vicinity)

Test Hole (No.)	Elevation (ft.)	Groundwater Elevation (ft.)(*)	Observations
1	375.309	-	No groundwater
2	372.269	-	No groundwater
3	378.679	-	No groundwater
4	380.069	Not available	Rotary Hole
5	372.269	-	No groundwater
6	336.159	Not available	Rotary Hole
7	328.589	316.589	Outwash sand, gravel
8	325.469	316.019	Outwash sand, gravel
9	325.469	316.019	Observation Well for #8
10	322.449	315.449	Outwash sand, gravel
11	379.039	357.689	Ice Contact sand, gravel
12	378.239	359.739	Ice Contact sand, gravel
13	344.974	322.874	Outwash sand, gravel
14	328.899	315.259	Ice Contact sand, gravel
15	328.899	315.259	Observation Well for #14
16	344.974	322.874	Observation Well for #13
17	Unknown	Not available	Soil Samples by Rotary

Notes.

(*) Observation dates for groundwater levels were as follows:

#7	11/20/1976	#12	12/08/1976
#8	11/21/1976	#13	12/22/1976
#9	11/21/1976	#14	12/18/1976
#10	12/01/1976	#15	12/18/1976
#11	12/06/1976	#16	12/22/1976

In the approximately one month period (between 11/20 and 12/20/76) there was a general drop of about 1.0 ft. in groundwater levels.

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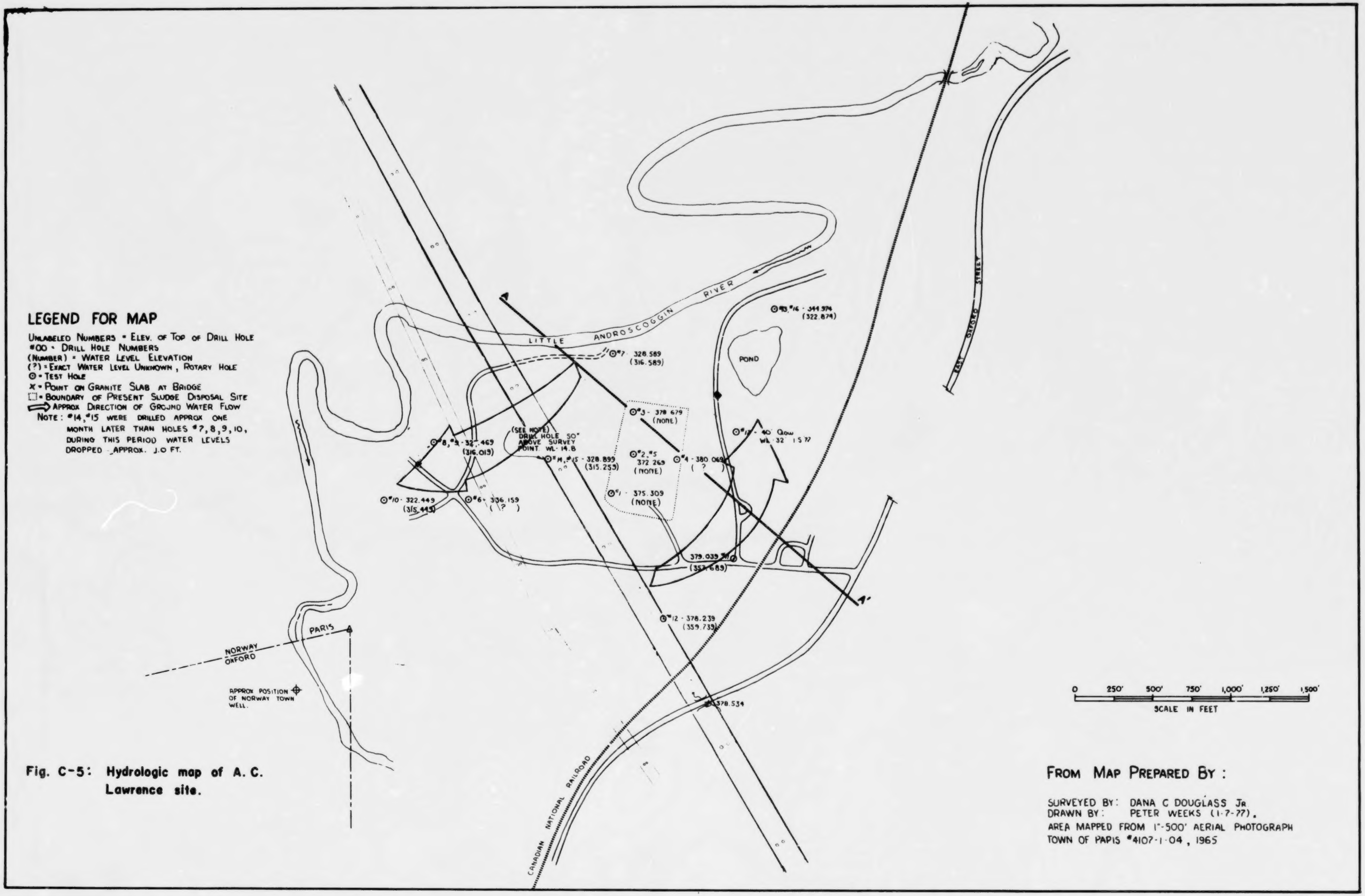

LEGEND FOR MAP
UNLABELED NUMBERS = ELEV. OF TOP OF DRILL HOLE
#00 = DRILL HOLE NUMBERS
(NUMBER) = WATER LEVEL ELEVATION
(?) = EXACT WATER LEVEL UNKNOWN, ROTARY HOLE
⊙ = TEST HOLE
x = POINT ON GRANITE SLAB AT BRIDGE
⬚ = BOUNDARY OF PRESENT SLUDGE DISPOSAL SITE
⇨ APPROX DIRECTION OF GROUND WATER FLOW
NOTE: #14, #15 WERE DRILLED APPROX ONE MONTH LATER THAN HOLES #7, 8, 9, 10, DURING THIS PERIOD WATER LEVELS DROPPED APPROX. 1.0 FT.
LITTLE ANDROSCOGGIN RIVER
POND
EAST OXFORD STREET
CANADIAN NATIONAL RAILROAD
PARIS
NORWAY
OXFORD
APPROX POSITION OF NORWAY TOWN WELL
#7 · 328.589
(316.589)
#13, #16 · 344.974
(322.874)
#3 · 378.679
(NONE)
#17 · 40' Qow
WL 32' 1 5 77
(SEE NOTE)
DRILL HOLE 50" ABOVE SURVEY POINT. WL 14.8
#8, #9 · 32_.469
(316.019)
#14, #15 · 328.899
(315.253)
#2, #5
372.269
(NONE)
#4 · 380.069
(?)
#1 · 375.309
(NONE)
#10 · 322.449
(315.445)
#6 · 336.159
(?)
379.039 #11
(357.689)
#12 · 378.239
(359.739)
378.534
A'
0
250'
500'
750'
1,000'
1,250'
1,500'
SCALE IN FEET

Fig. C-5: Hydrologic map of A. C. Lawrence site.

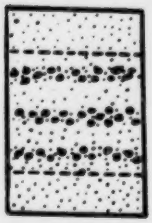
FROM MAP PREPARED BY:

SURVEYED BY: DANA C DOUGLASS JR
DRAWN BY: PETER WEEKS (1-7-77).
AREA MAPPED FROM 1"-500' AERIAL PHOTOGRAPH
TOWN OF PAPIS #4107-1-04, 1965

Table C-7

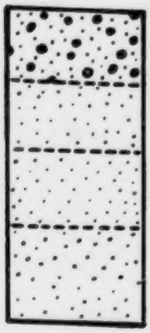
Test Hole Descriptions, A.C. Lawrence Site and Vicinity, South Paris

Test Hole #6



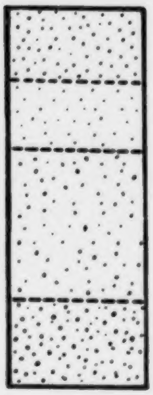
0'-16'	Medium to fine grained, uniform sand.
16'-96'	Coarse to very coarse grained, sandy, stratified, well-rounded gravel.
96'-118'	Medium to coarse grained, very angular, very compact sand.

Test Hole #7



0'-20'	Medium to coarse grained, gravelly, uniform, brown sand.
20'-60'	Fine to medium grained, very uniform, brown sand.
60'-95'	Fine to medium grained, clayey, very uniform, brown sand.
95'-103.5'	Medium to coarse grained, uniform, brown sand.
103.5'	Refusal.

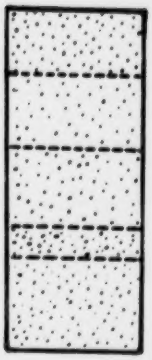
Test Hole #8



0'-25'	Medium to coarse grained, uniform, gray sand.
25'-55'	Fine to medium grained, very uniform, gray sand.
55'-76'	Medium to coarse grained, uniform, compact, greenish gray sand. (Took considerable water.)
76'-82.4'	Coarse grained, subangular, uniform, greenish gray sand.
82.4'	Refusal.

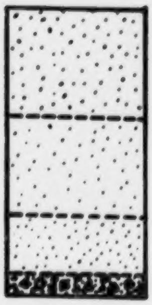
Table C-7
(Continued)

Test Hole #10



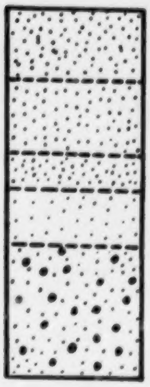
0'-20'	Medium to fine grained, silty, light brown sand.
20'-50'	Medium to fine grained, light brown, grayish sand. (Took some water.)
50'-70'	Medium grained, uniform, light brown, grayish sand. (Took considerable water.)
70'-75'	Medium to coarse grained, uniform, greenish gray sand. (Took considerable water.)
75-'84'	Medium to fine grained, silty, greenish gray sand.
84'	Refusal.

Test Hole #11



0'-15'	Medium to coarse grained, uniform, brown sand.
15'-25'	Fine grained, silty, uniform, brown sand.
25'-41'	Very fine grained, silty, clayey, brown sand.
41'-43'	Very coarse, angular, highly compact, gravel.
43'	Refusal.

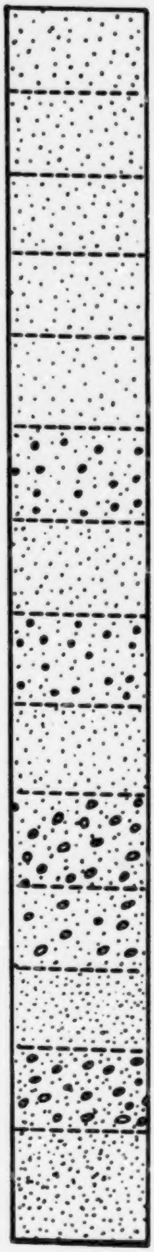
Test Hole #12



0'-10'	Very coarse to medium grained, brown sand. (Some iron cementing noted.)
10'-25'	Medium to coarse grained, uniform, brown sand.
25'-27'	Medium to coarse grained, red sand.
27'-30'	Medium to fine grained, brown sand.
30'-41'	Medium to fine grained, pebbly, greenish sand.
41'	Refusal.

Table C-7
(Continued)

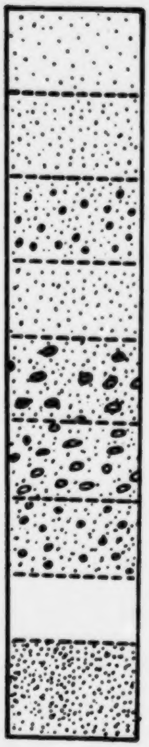
Test Hole #13



0'-5'	Coarse to fine grained, subangular, brown sand.
5'-10'	Coarse to medium grained, uniform, subangular, blackish brown sand.
10'-15'	Medium to coarse grained, uniform, subangular, brownish black sand.
15'-20'	Medium to fine grained, uniform, subangular, grayish brown sand.
20'-25'	Medium to coarse grained, very uniform, subangular sand.
25'-30'	Medium to coarse grained, clayey, pebbly, brownish tan sand.
30'-35'	Medium to coarse grained, uniform, subangular, brownish tan sand.
35'-40'	Medium to coarse grained, pebbly, very uniform, subangular, tan sand.
40'-45'	Coarse to medium grained, very uniform, subangular, tan sand.
45'-50'	Coarse to medium grained, gravelly, uniform, subangular, tan sand.
50'-55'	Coarse to medium grained, gravelly, uniform, subangular, brownish gray sand. Hole took water.
55'-60'	Fine to medium grained, very uniform, subangular, gray sand. Hole took water.
60'-65'	Fine to medium grained, gravelly, uniform, subangular, gray sand.
65'-70.6'	Fine to coarse grained, gravelly, subangular, gray sand.
70.6'	Refusal.

Table C-7
(Continued)

Test Hole #14



0'-10'	Medium grained, very uniform, reddish brown sand.
10'-20'	Medium to coarse grained, very uniform, subangular, iron stain (probably limonite or goethite), reddish brown sand.
20'-25'	Medium grained, pebbly, very uniform, subangular, light tan sand.
25'-30'	Medium grained, very uniform, subangular, light tan sand.
30'-35'	Medium to coarse grained, gravelly, uniform, subangular, light tan sand.
35'-40'	Coarse to medium grained, gravelly, uniform, subangular, light tan sand.
40'-45'	Very coarse to coarse grained, pebbly, uniform, subangular, light tan sand.
45'-55'	(Rock plugged bottom of casing, no sample obtained.)
55'-60'	Very fine, uniform, very compact sand. (Similar to till sample obtained in T1 through T3.)

In the case of wells #13 and #16, the screen in the pumped well (#13) was set between 60.6 and 70.6 ft from ground level and the screen in the observation well (#16) was set between 55 and 65 ft. For wells #14 and 15, the screen at the pumped well (#14) was set between 45 and 55 ft, and the screen in the observation well was between 55 and 60 ft.

The pump test data are presented in Tables C-8 through C-10.

(d) Analysis of Pump Tests

The analysis of pump test data is complicated by the heterogeneity of the site and by the possibility of recharge from the Little Androscoggin River. In general, the practice in analysis of nonsteady flow from partially penetrating wells is to use formulas for completely penetrating wells without adjustments; if adjustments are made, these are usually based on steady-state solutions for partial penetration. These procedures give fair results if the aquifer is of small and known thickness, provided the assumptions made in each case are applicable. However, the use of formulas for fully penetrating wells can lead to misleading results. The effects of partial penetration resemble the effects of some kind of recharge boundary, for example, infiltration from the river. Routine application of conventional analyses (for example, the Jacob method of solution for the Theis non-equilibrium radial flow formula toward a pumped well), may yield, in such cases, incorrect results. Accordingly, we estimate below a range of transmissibilities based on conventional formulas as well as on approximate results obtained by using the Hantush formulas for partially penetrating wells.

It should be noted that because of limitations in time and expense, the pump tests performed were of relatively short duration and were carried out within the usual precision of measurements in this area. These limitations have introduced uncertainties in the calculated values of transmissibility. In fact, only a lower bound can be placed on the value of transmissibility in some instances.

Table C-8

Pump Test on Wells #8 and #9

Pumped Well (#8) - Diameter: 2.5 in.
Depth of screen: 67.5 to 77.5 ft

Observation Well (#9) - Diameter: 2.5 in.
Depth of screen: 65 to 75 ft
Distance from pumped cell: 2.0 ft

Water Table Height: 71 ft

Date of tests: Nov. 30, 1976

Time	Water Level (ft)	Discharge Rate (gpm)	Drawdown (ft)
9:19	9.45	0	
:20	9.95	16	0.50
:21	10.50	16	1.05
:22	10.90	16	1.45
:23	11.05	16	1.60
:24	11.15	16	1.70
:25	10.95	13	1.50
9:30	10.90	13	1.45
:40	10.90	13	1.45
:50	10.95	13	1.50
10:00	10.95	13	1.50
:30	10.95	13	1.50
11:00	10.95	13	1.50
:01	10.30	0	0.85
:02	10.05	0	0.60
:03	9.90	0	0.45
:04	9.80	0	0.35
:05	9.70	0	0.25
:06	9.70	0	0.25
:07	9.65	0	0.20
:08	9.65	0	0.20
:10	9.65	0	0.20

Table C-9

Pump Test on Wells #14 and #15

Pumped Well (#14) - Diameter: 2.5 in.
Depth of screen: 45 to 55 ft

Observation Well (#15) - Diameter: 2.5 in.
Depth of screen: 55 to 60 ft
Distance from pumped well: 2.0 ft

Water Table Height: 45 ft

Date of tests: Dec. 18, 1976

Time	Water Level (ft)	Discharge Rate (gpm)	Drawdown (ft)
9:00	15.80	0	
:14	15.80	0	
:15	16.20	50	0.40
:16	16.25	50	0.45
:17	16.25	50	0.45
:18	16.25	50	0.45
:19	16.25	50	0.45
:20	16.30	50	0.50
9:25	16.30	50	0.50
:30	16.30	50	0.50
:35	16.30	50	0.50
:40	16.30	50	0.50
:50	16.30	50	0.50
10:00	16.30	50	0.50
:30	16.30	50	0.50
11:00	16.40	50	0.60
12:00	16.30	50	0.50
1:00	16.40	50	0.60
2:00	16.40	50	0.60
2:15	16.40	50	0.60
:16	16:00	0	0.2
:17	16.00	0	0.2
:18	15.90	0	0.1
:19	15.90	0	0.1
:20	15.90	0	0.1
:25	15.90	0	0.1
:35	15.90	0	0.1
:40	15.90	0	0.1

Table C-10

Pump Test on Wells #13 and #16

Pumped Well (#13)	-	Diameter: 2.5 in. Depth of screen: 60 to 70 ft
Observation Well (#16)	-	Diameter: 2.5 in. Depth of screen: 55 to 65 ft Distance from pump well: 3 ft
Water Table Height:		57 ft
		Date of tests: Dec. 22, 1976

Time	Water Level (ft)	Discharge Rate (gpm)	Drawdown (ft)
9:10	23.2	0	0
:42	23.2	10	0
:43	23.5	10	0.3
:44	23.5	10	0.3
:45	23.6	10	0.4
:46	23.6	10	0.4
:47	23.6	10	0.4
:48	23.6	10	0.4
:49	23.6	10	0.4
:50	23.6	10	0.4
:55	23.6	10	0.4
10:00	23.6	10	0.4
11:00	23.6	10	0.4
12:00	23.6	10	0.4
1:00	23.6	10	0.4
1:00	23.6	0	0.4
:51	23.6	0	0.4
:52	23.4	0	0.2
:53	23.3	0	0.1
:54	23.3	0	0.1
:55	23.3	0	0.1
:56	23.3	0	0.1
:57	23.3	0	0.1
:58	23.3	0	0.1
:59	23.2	0	0

(i) Pump Tests on Wells #8 and #9: Drawdown and recovery data for these tests are shown in Fig. C-6 (which also includes a schematic of the test arrangement).

If we use the conventional Jacob method for solution of the Theis non-equilibrium solution for fully penetrating wells, the results would be expressed as

$$s = \frac{2.303\ Q}{4\pi T} \log \frac{2.25\ T\ t}{r^2 S}$$

where s is drawdown (ft)

Q is the pumping rate (ft^3/min)

T is the transmissibility (ft^2/min)

t is the time from the beginning of pumping (min)

r is the distance from the pumping well (ft)

S is the storage coefficient

This approximation can be used provided $u = \frac{r^2 S}{4Tt} < 0.02$. From the data of Fig. C-6, we would estimate

$$T \cong \frac{(2.303)\ (2\ ft^3/min)}{4\pi\ (2\ ft/log\ cycle)} \cong 0.2\ ft^2/min$$

The corresponding value of K, the hydraulic conductivity, would be

$$K = T/H = 0.2\ ft^2/min/71\ ft \simeq 3 \times 10^{-3}\ ft/min$$

where H is the height of water table (see Table C-8).

According to this analysis, we would attribute deviations from linearity at about 4 min (see Fig. C-6) to recharge from the Little Androscoggin River. However, the use of the Jacob approximation for fully penetrating wells on which this interpretation rests, is not reliable for

C-32

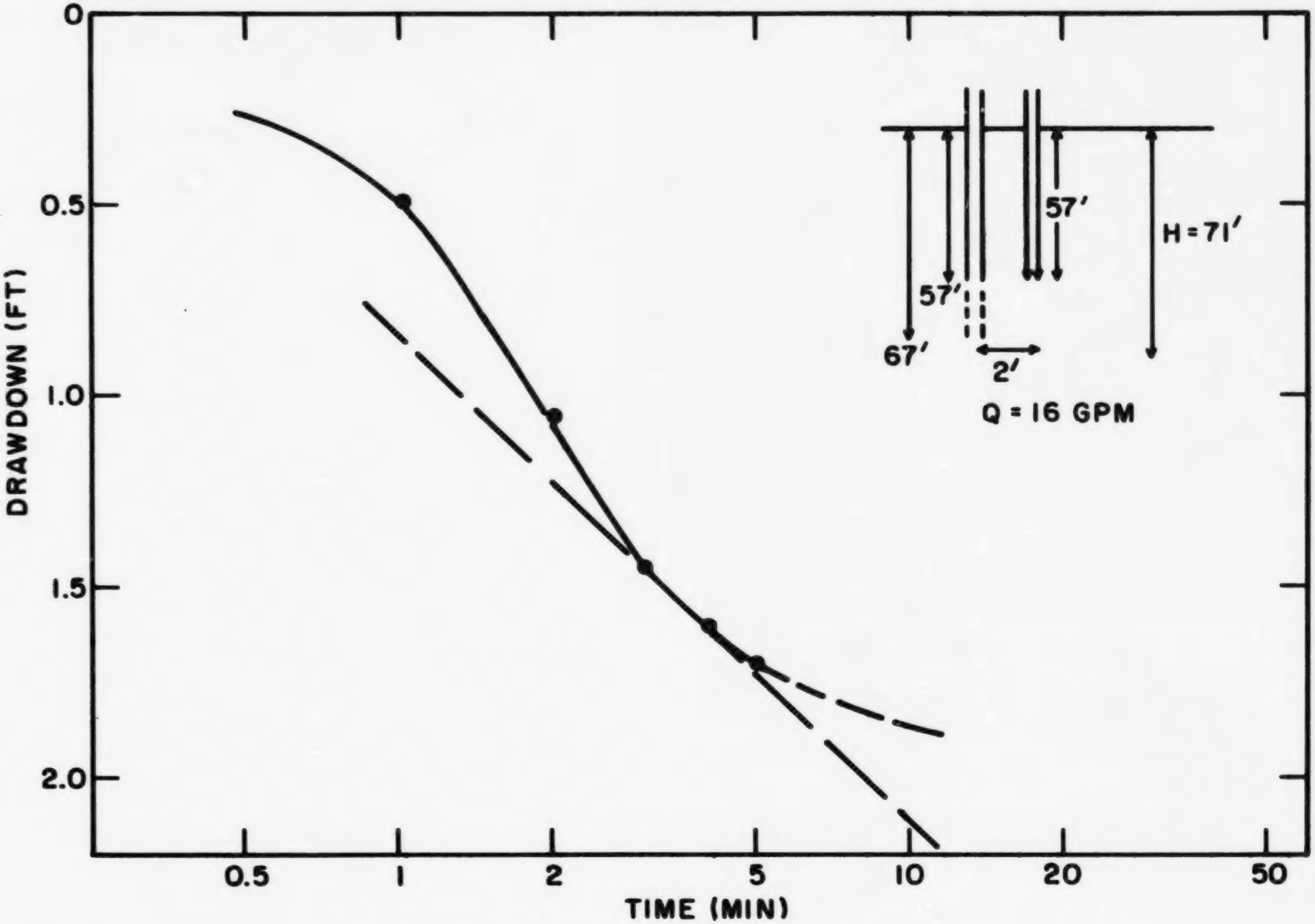


Fig. C-6: Drawdown test for Wells #8 and #9.

$u > 0.02$. We note that if $T \sim 0.2$ ft^2/min and since $S \simeq 0.2$, the value of u for $t \sim 4$ min is

$$u = (4)(0.2)/(4)(0.2)(4) \sim 0.25$$

a value significantly greater than the upper limit of the linear approximation. Furthermore, the suggestion that departure from linearity is attributable to recharge is difficult to reconcile with the general expectation that recharge from the river will not be significant until $x/\sqrt{4Tt/S} < 10$ with $\underline{x}$ the distance from the river. Since $x \sim 200$ ft and $S \sim 0.2$, recharge effects are not likely to be significant until $t > 100$ min.

An alternative approach to the interpretation of the data is to take into account the partially penetrating nature of the well and use a Hantush formula for the particular geometry employed (see M.S. Hantush "Aquifer Tests on Partially Penetrating Wells" Proc. Am. Soc. Civil Eng. 87, HY5,2943, 1961). The drawdown is given by

$$S = \frac{Q}{8\pi K\ (\ell-d)}\ E(u, \frac{l}{r}, \frac{d}{r}, \frac{z}{r})$$

where $\underline{\ell}$ is the total penetration length and $\underline{d}$ the penetration length of the pumped well which is not screened (i.e. $(\ell-d)$ is the height of the screen); and $\underline{z}$ is the depth of the observation well, here treated as a piezometer, since it was screened for a short length only. The function E is given by

$$E = M(u, \frac{\ell+z}{r}) - M(u, \frac{d+z}{r})$$

$$+ M(u, \frac{\ell-z}{r}) - M(u, \frac{d-z}{r})$$

where $M(u,\beta)$ is an indefinite integral values of which have been tabulated for a wide range of u and β, and u is the well function (see above).

For the particular conditions employed here

$\ell = 67.0$ ft
$d = 57.0$ ft
$z = d = 57.0$ ft
$r = 2.0$ ft

Accordingly,

$$E = M(u,62) - M(u,57) + M(u,5.0)$$

For the range of u values of concern here

$$M(u,62) = M(u) = M(u,57)$$

Therefore, the E function reduces to $M(u,5.0)$, and the equation for drawdown is

$$S = C\ M(u,5.0)$$

where C = constant = $Q/8\pi K\ (\ell - d)$. This expression is of the "special equation" type and is expected, in general, to show an inflection point assuming small values of r/H, as is the case here ($r/H = 2/71 \sim 0.03$). The inflection point is located by the relation $\beta^2/\sqrt{\pi} = f(x) = xe^{x2}\ \mathrm{erf}(x)$ in which $x = \beta\sqrt{u_i}$ with u_i the value of u when $t = t_i$, the time corresponding to the inflection point. The drawdown at the inflection point is

$$S_i = C\ M(u_i,\beta)$$

and the slope of the curve at that point is

$$m_i = \frac{\Delta S}{\text{cycle}} = 2.30\ C\ e^{-u_i}\mathrm{erf}(x)$$

Application of this analysis to the data (see Fig. C-6) involves at least one iteration since it is not possible to locate precisely the tangent to the curve at the inflection point. If, as a first approximation, we take the straight line portion as approximating the tangent to the curve, we have $m_i = 2.0$ ft/cycle. The other quantities are:

$$C = Q/8\pi(\ell-d)K = Q/250K$$

$$f(x) = \beta^2/\sqrt{\pi} = 11.2 \quad ; \quad x = 1.445 \quad ; \quad \mathrm{erf}(x) = 0.96$$

$$u_i = (x/\beta)^2 = 0.08 \text{ and } e^{-u_i} = 0.92$$

Accordingly, with $Q = 2.1$ ft^3/min,

$$K = \frac{(2.1)(2.303)(0.92)(0.96)}{(250)(2.0)} = 0.0085 \text{ ft/min}$$

or

$$T = (71)(0.0085) = 0.60 \text{ ft}^2\text{/min}$$

If we calculate S_i from

$$S_i = C\ M(u_i, 5.0) \text{ with } u_i = 0.08,\ M(u_i\beta) = 2.014$$

we have

$$S_i = \frac{(2.1)}{(250)(0.0085)}(2.014) = 2 \text{ ft}$$

a value clearly too high (see Fig. C-6). A choice of $S_i = 1.5$ ft, would yield $m_i = 1.5$ ft/log cycle (see Fig. C-6). Use of these values in the equations above yields

$$K = 0.013 \text{ ft/min or } T = 0.90 \text{ ft}^2\text{/min}$$

and

$$S_i = \frac{(2.1)}{(250)(0.013)} = 1.5 \text{ ft}$$

This choice yields consistent results. Accordingly, we take $T = 0.90$ ft^2/min.

Recovery data from these tests are shown in Fig. C-7. The same analysis as above can be applied. The slope of the curve at about $t/t' \sim 102/100$ is 0.9 ft/min. Application of the corresponding equation for recovery with $Q = 13$ gal/min yields

$$K = \frac{(2.3)(1.70)}{(250)(0.9)} [(1.020)(0.92)(0.96)]$$

$$K = 1.5 \times 10^{-2} \text{ ft/min}$$

and

$$T = 1.1 \text{ ft}^2\text{/min}$$

which is to be compared with 0.9 ft^2/min obtained previously. Accordingly, the value of T is estimated as 1 ft^2/min.

(ii) Tests on Wells #14 and #15: Pumping and recovery tests on wells #14 and #15 are shown in Figs. C-8 and C-9. As is evident from these figures, the value of u is such that the curves cannot be analyzed reliably (except at times of the order of less than 1 min for which data are not available). The shift to smaller times implies higher transmissibilities (since $u = r^2S/4Tt$) than at test well #8. A conservative estimate of transmissibility would be about 8 to 10 times that at well #8. The geometry was the same for both tests, but well #14 was pumped at 50 gpm (as against 13 gpm) and the drawdown was about 0.5 ft (as against 1.5 ft). A transmissibility of about 10 ft^2/min would be equivalent to shifting the time axis to smaller times by a factor of 10 and would be consistent with the observations recorded (Figs. C-8, C-9).

(iii) Tests on Wells #13 and #16: Pumping and recovery tests on wells #13 and #16 are shown in Figs. C-10 and C-11. Remarks made above

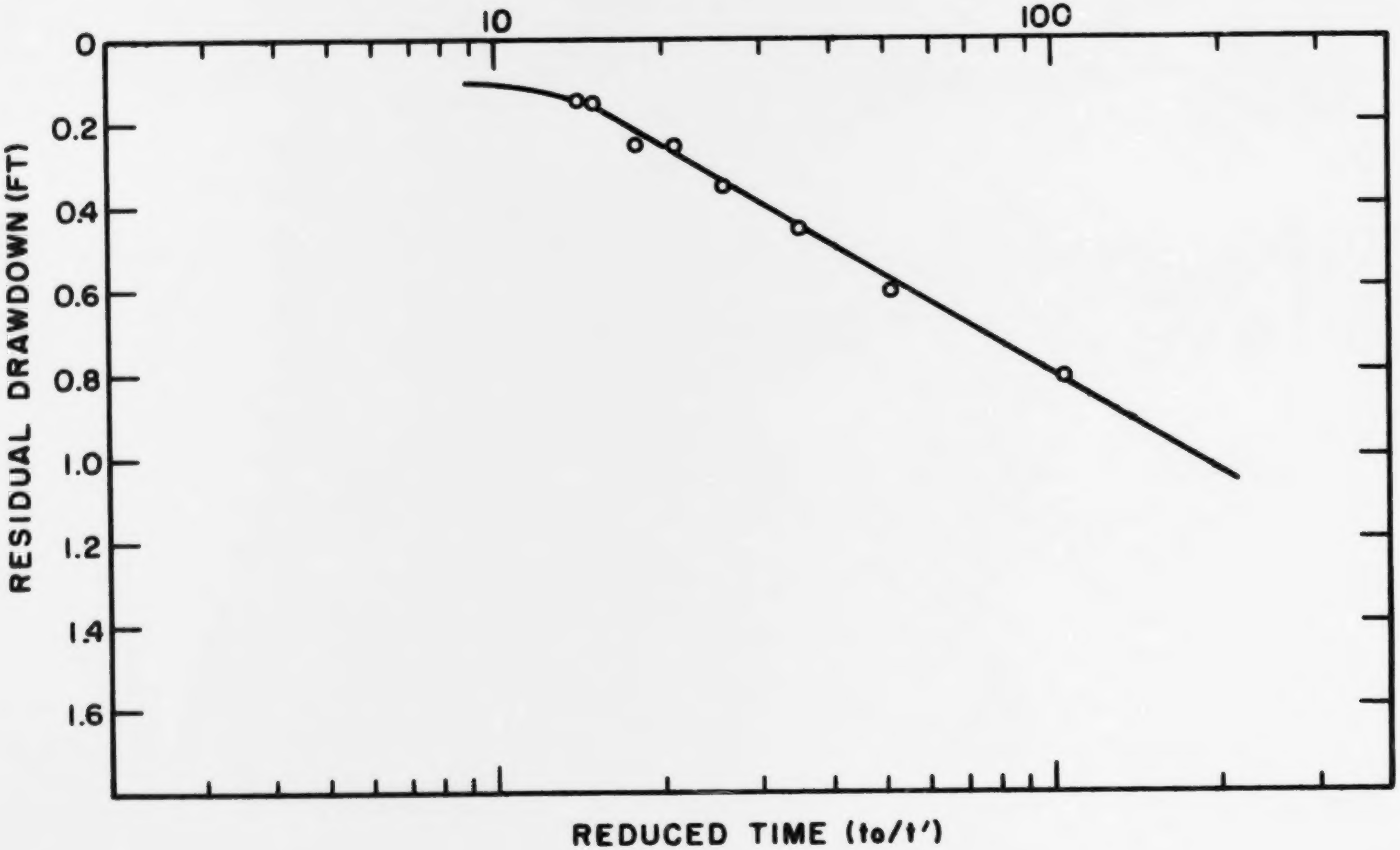


Fig. C-7: Recovery test for Wells #8 and #9.

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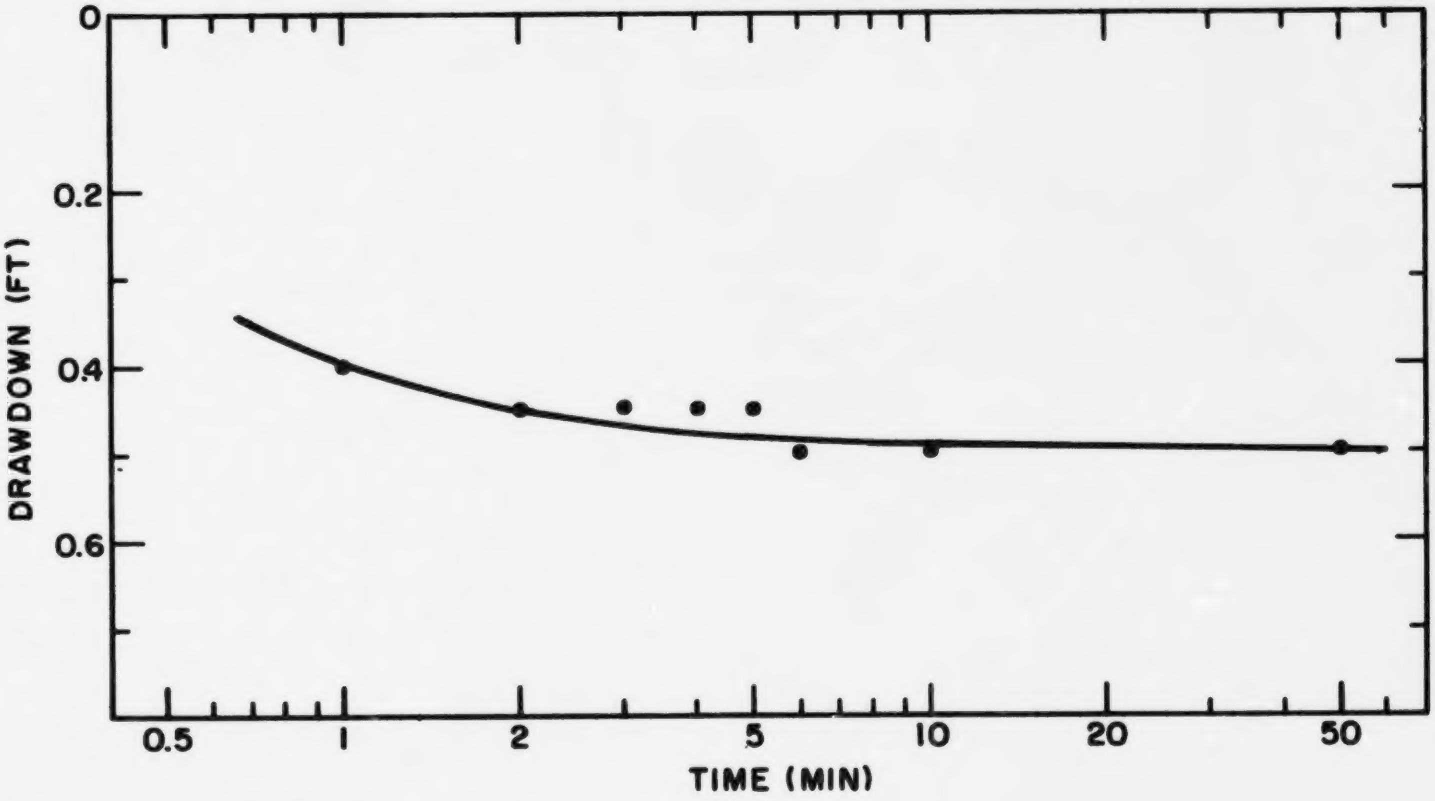

Fig. C-8: Drawdown test for Wells #14 and #15.

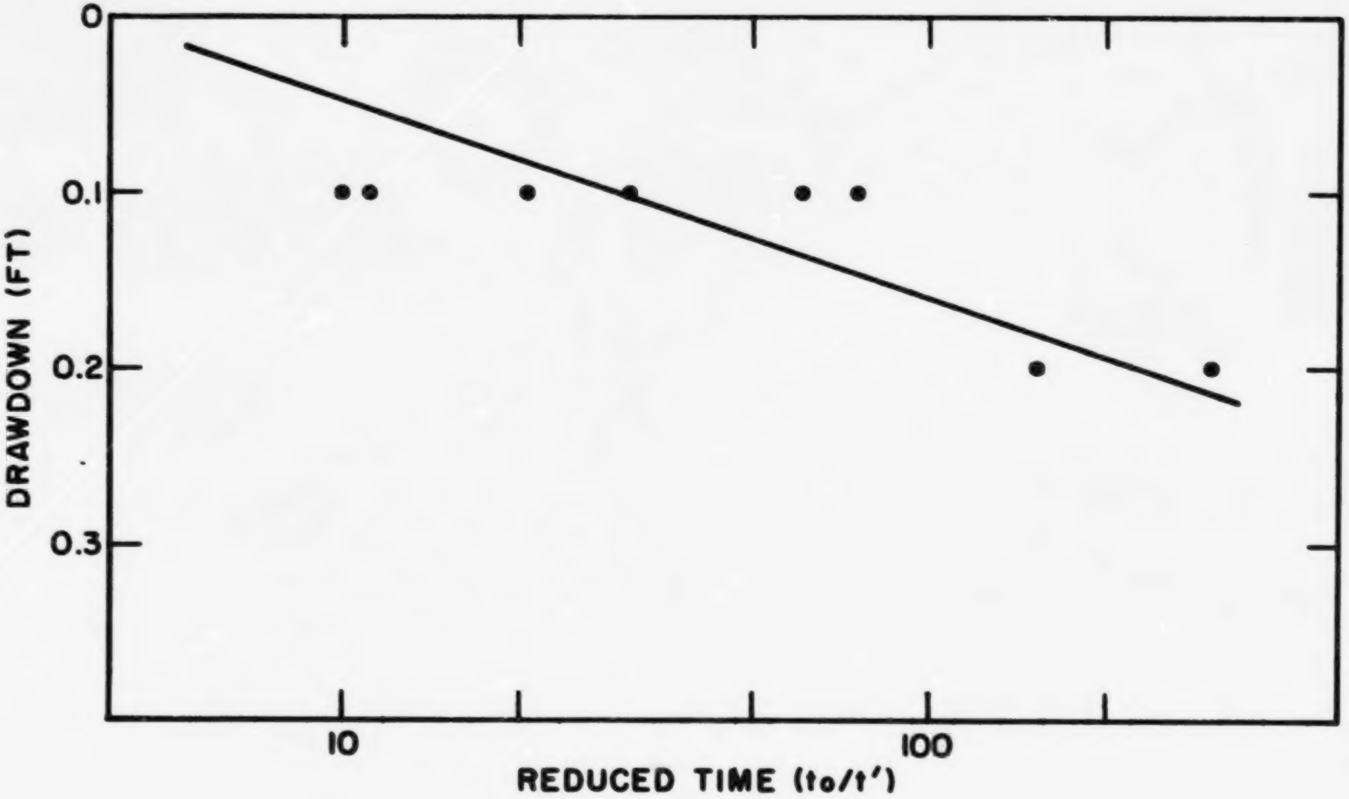

Fig. C-9: Recovery test for Wells #14 and #15.

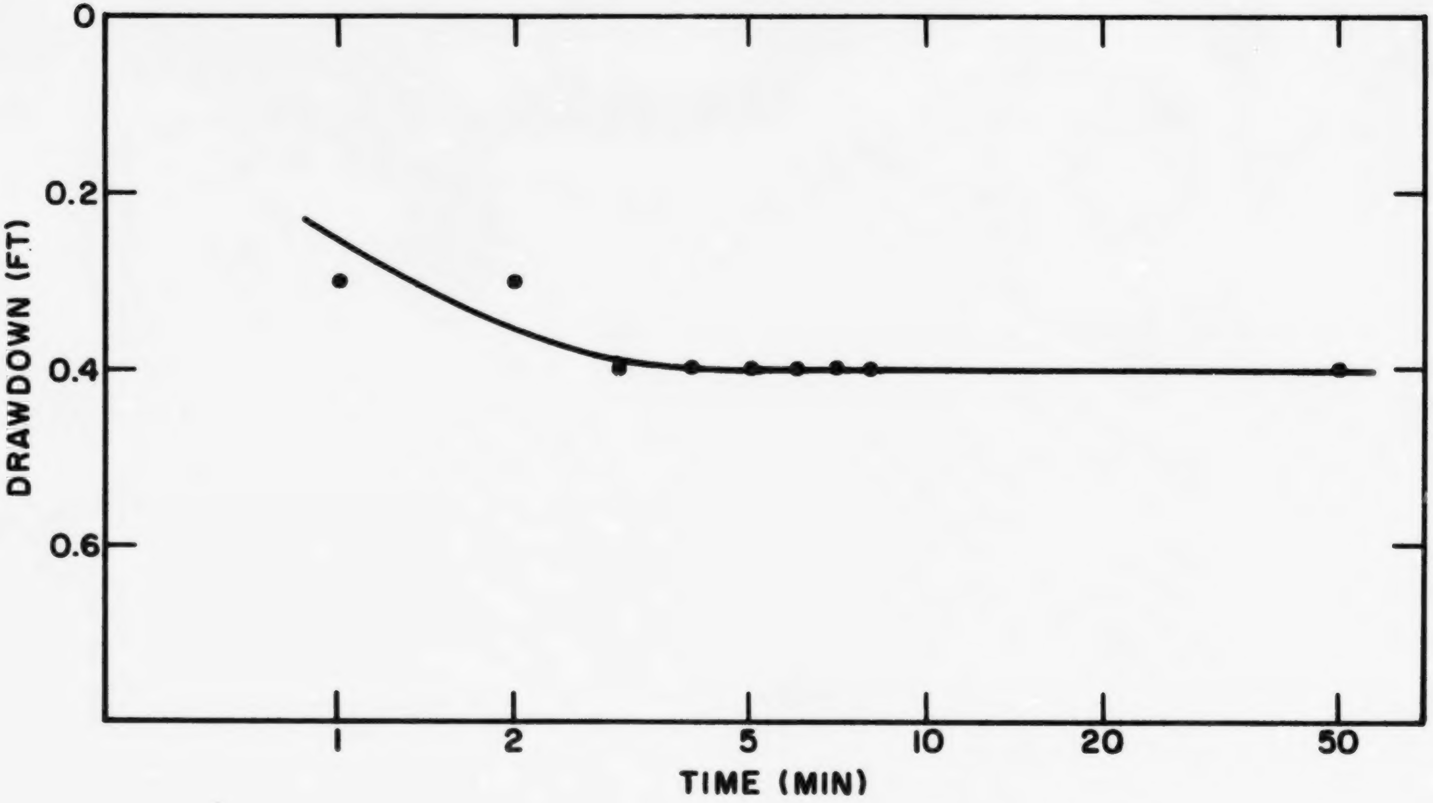

Fig. C-10: Drawdown test for Wells #13 and #16.

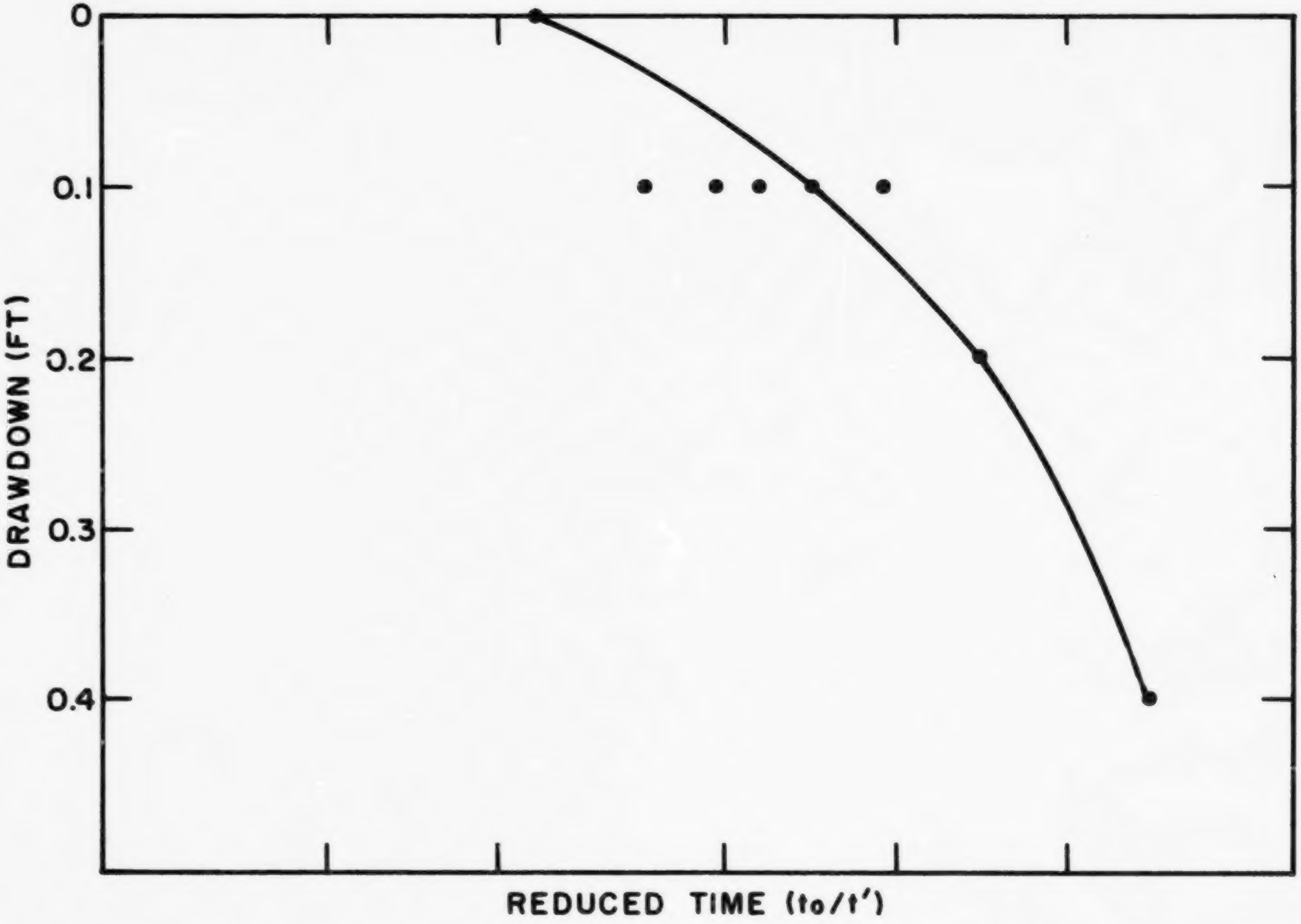

Fig. C-11: Recovery test for Wells #13 and #16.

for wells #14 and #15 are applicable to these tests also. An estimate of the transmissibility would be about 3 times that of well #8.

(e) Hydrological Characterization of A. C. Lawrence Site

The general movement of groundwater at the A. C. Lawrence site is depicted by the arrows in Fig. C-5. Groundwater moves in a northerly direction on the eastern half of the site with a steep gradient (approximately 35 ft drop in water table height between wells #11 and #13). The groundwater movement is in a westerly direction (along the river) in the northern part of the site; and in a south direction (again along the river) along the western boundary of the site. It is clear that the protrusion of till in the central portion of the site controls local hydrology by providing an essentially impermeable boundary to groundwater.

Flow velocities can be estimated from transmissibilities and water table heights. They range from about 2 ft/day at the eastern boundary of the site, to about 0.5 ft/day at the northern boundary, and to about 0.02 ft/day along the western part of the site.

A schematic representation of groundwater along the cross section AA' (see Fig. C-5) is given in Fig. C-12.

4. Chemical Analyses of Soils at the A. C. Lawrence Site

(a) Chemical Analyses of Soils

Soil samples from augered holes in areas with old sludge deposits were analyzed to establish vertical distributions of chromium and other constituents. The analyses were carried out by digesting 2 or 4 g of sample with 15 cc of 0.1N or 1.0N HNO_3 for 90 min; the suspension was centrifuged and the solids were again digested for 90 min with 15 cc HNO_3. After filtration (0.42 μ filter), the filtrate was analyzed for chromium (by atomic absorption).

Results with samples from augered hole #13 are shown in Table C-11. As expected, high concentrations of Cr are found in layers con-

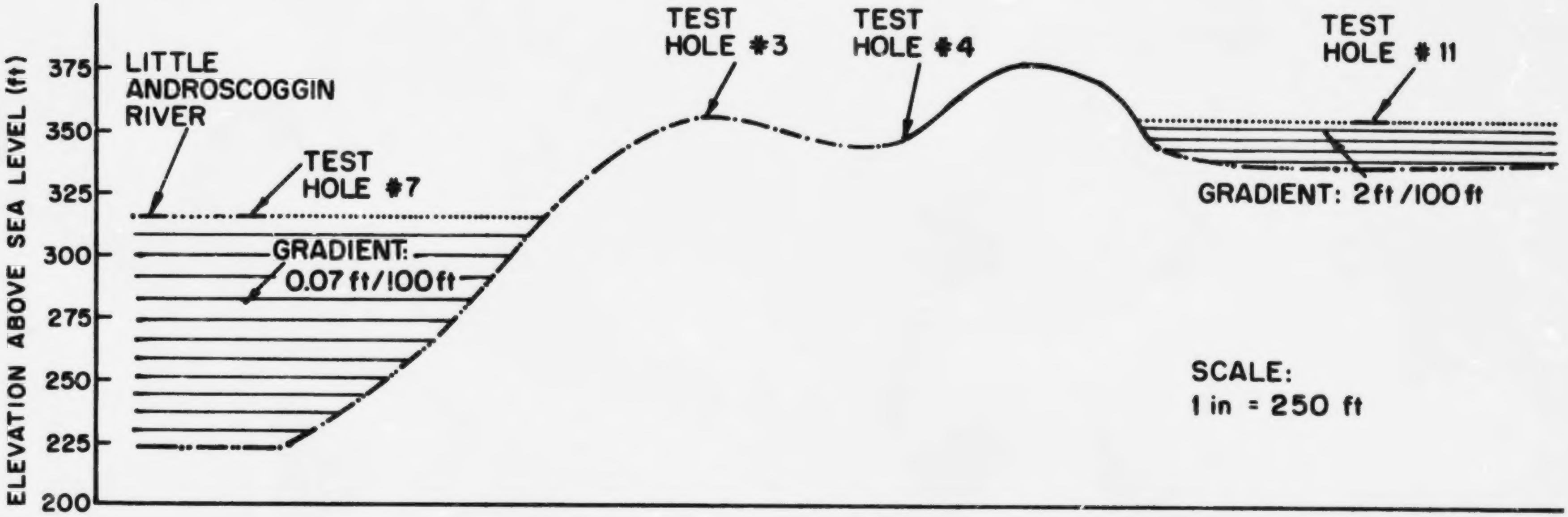
TEST HOLE #3
TEST HOLE #4
TEST HOLE # 11
LITTLE ANDROSCOGGIN RIVER
TEST HOLE #7
GRADIENT: 0.07 ft/100 ft
GRADIENT: 2 ft/100 ft
SCALE: 1 in = 250 ft
ELEVATION ABOVE SEA LEVEL (ft)
375
350
325
300
275
250
225
200

Fig. C-12: Schematic representation of groundwater at the A.C. Lawrence site.

Table C-11

Soil Analyses for Chromium Auger Hole No. 3(1)

Depth (feet)		Total Chromium(2) 0.1N HNO_3 (ppm)	1.0N HNO_3 (ppm)
Surface		8.1	4,450
2'	(sludge)	12.9	7,000
3'	(sludge)	124.0	1,950
4'	(sludge)	13.7	7,020
7'	(sand)	88.4	415
8.5'	(sand)	98.4	1,470
10'	(sand)	95.2	272
12'	(sand)	398.0	421
14'	(sand)	298.0	467

---

(1) See Fig. C-3 for location of auger hole #3.

(2) Background Cr in soils extracted by 1.0N HNO_3 was 4.14 ppm and 5.32 ppm.

taining sludge. However, appreciable quantities (∿ 400 ppm) were also observed below the sludge deposits where no sludge was evident.

There are significant differences in the amount of Cr extracted with 0.1 and 1.0M HNO_3 from layers containing sludge. Apparently, organic material in the sludge reacts with HNO_3; if dilute acid is used, the acid is exhausted and Cr extraction is incomplete.

Table C-11 suggests that appreciable amounts of Cr are found below old sludge deposits. Accordingly, more extensive tests were undertaken to establish its distribution, elucidate the mechanism of distribution, and assess its significance in terms of possible impacts on water quality.

Soil samples were obtained with a rotary drill at test hole #17 (see Fig. C-5) by blowing the drillings with air. Samples collected periodically from various depths down to the water table were analyzed as previously described for Cr. Results are shown in Table C-12 and plotted in Fig. C-13.

The concentration of Cr is high throughout the first 10 ft where old sludge deposits were clearly present. The water content is also high (up to 24%), indicating that the sludge has remained relatively wet over the years. Once the sludge layer is traversed, the Cr content decreases very rapidly with depth and is at background levels at 20 ft. Moisture content also falls to about 1 to 1.5%. At about the water table, i.e., at 30 to 35 ft, the amount of Cr increases to about 100 ppm and then drops again relatively quickly to background values.

To understand the origin of the vertical distribution of Cr found beneath old sludge deposits it is useful to recollect that old sludge (contrary to currently produced sludge) was not dewatered. Effluent from the tannery was allowed to settle in ponds and the wet sediment was then removed (by excavation) and dumped at the Lawrence site. In dredging the bottom sediments of the settling lagoons, sand as well as sludge was probably removed and the wet mixture of the two was deposited at the Lawrence site. It is not known whether the sludge was deposited on the surface or whether the dumping site was partially excavated. In any case, it is probable that appreciable liquid flowed from the sludge and eventually

Table C-12

Soils Analysis for Cr and Sodium(1)

Test Hole #17

Sample	Depth	H_2O (wt %)	Cr(2) (ppm)	Na(2) (ppm)	Comments
7	0-5'	13.1	1,980	122	Sand & Sludge
8		18.0	1,200	148	
9		12.7	2,410	124	
10	5'-7'	24.4	12,110	327	Sand & Sludge
11		11.3	3,530	167	
12	7'-10'	23.9	4,120	407	Sludge
13	10'-15'	2.02	43.0	82.6	Sand & Sludge
15		3.65	59.2	95.0	
16		2.65	27.6	79.6	
17	15'-20'	2.30	16.2	93.7	Sand & Sludge
18		3.42	95.2	115.	
19		3.98	50.3	106.	
20	20'-25'	1.11	16.9	97.6	Sand
21		1.40	14.1	104	
22	25'-30'	1.73	14.1	86.0	Sand
23		1.71	12.3	94.2	
24		1.50	9.5	92.7	
25	30'-35'	15.6	13.0	111	Sand, Wet
26		13.0	34.3	108	
27		12.7	99.0	173	
28	35'-40'	17.8	26.4	157	Wet Sand
29		17.2	15.8	132	
30		17.2	12.6	93.5	

---

(1) The location of test hole #17 is shown in Fig. C-5.

(2) Extracted by refluxing with concentrated nitric acid three times (approximately 6 cc and for each gram of sample).

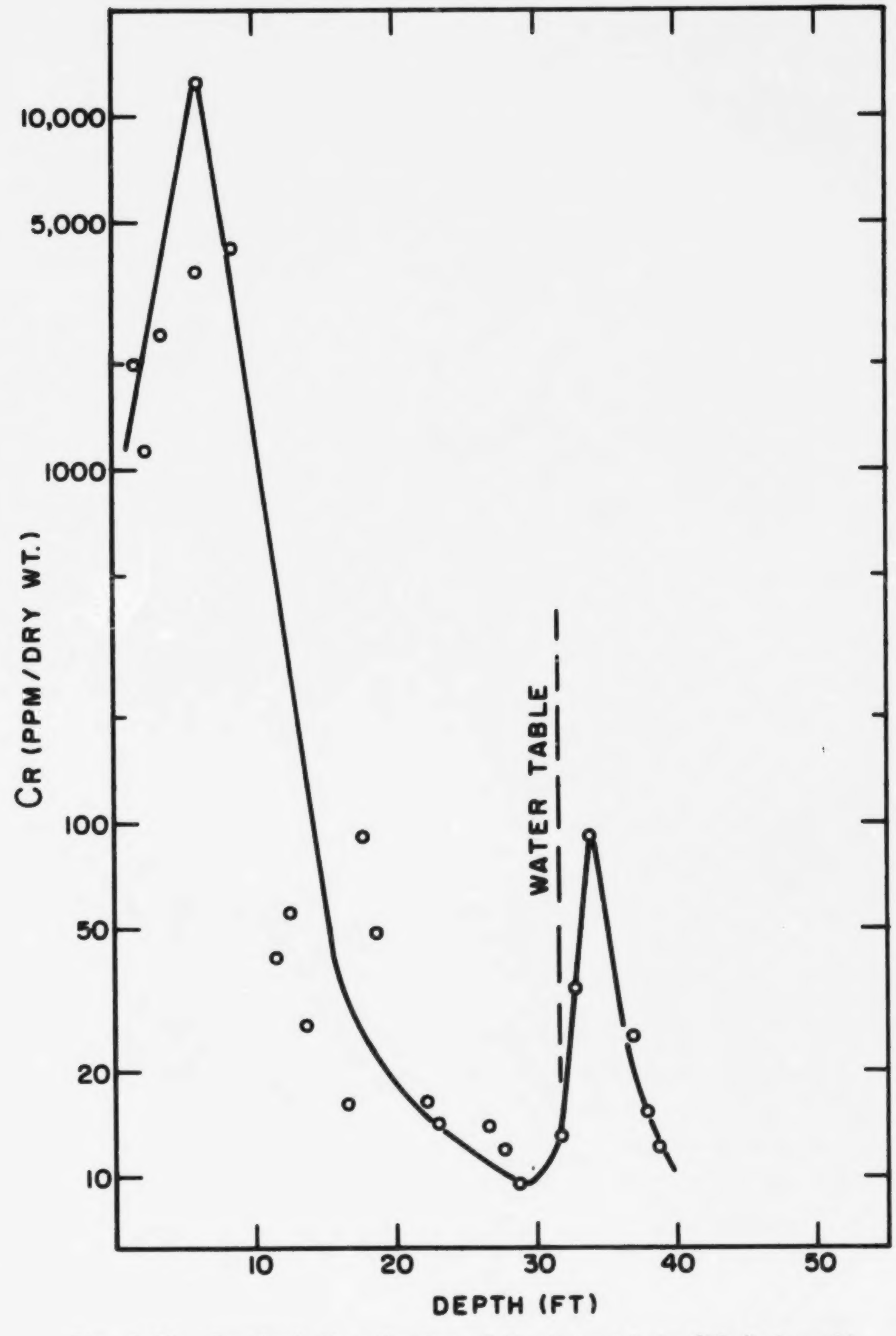

Fig. C-13: Vertical distribution of Cr at test hole #17 (below old sludge deposits).

entered the groundwater. It is a reasonable assumption that particles containing chromium were carried downward by this flow, aided perhaps by infiltrating rainwater, and that some were trapped and accumulated at the water table.

If the account suggested above is correct, there should also be an increase in the proportion of small particles of sand at the water table. Results of sieve analyses of samples taken at various depths are given in Table C-13. Figure C-14 shows the percentage of particles which are passed by an 80 mesh screen as a function of depth. It is clear that the percentage of fines (both < 80 mesh and < 200 mesh) rises substantially when the water table is encountered. For example, the percentage of fines (particles that pass a 200 mesh screen) is generally about 1.5 to 2.5%; however, at the water table it rises to about 14%. Similarly, the percentage of particles that go through an 80 mesh screen rises from about 5% to almost 50%. Obviously, there was vertical sorting of fine particles, probably aided by infiltrating raining, with accumulation of fines at the water table.

In view of these results, there was another contributing factor to the accumulation of particles of Cr (or particles containing Cr) at the water table, namely, the decrease in porosity of the host material through which the Cr particles moved. A bed of particles with smaller average size implies a smaller pore size and lower overall porosity.

Some further analyses of these samples were carried out to ascertain the distribution of Cr among the various sieved fractions. Results are given in Table C-14. It is clear that a higher percentage of Cr is found in the fine fraction than in the rest of the sample. Thus, for sample 22, the total fraction of particles less than 200 mesh is 1.38% but the Cr content of this fraction accounts for 9.3% of the total Cr. These results again suggest that Cr was carried downward as fine particles.

That Cr was carried downward in the form of particles - and not by a dissolution/deposition mechanism - is further supported by analyses of water in contact with the Cr at the water table. The water samples

Table C-13

Sieve Analysis of Samples from Test Hole #17

Sample[1]	Depth (ft)	Weight Per Cent					
		Mesh > 10	> 20	> 80	> 200	> 325	< 325
9	0-5'	22.04	16.75	42.85	11.07	4.5	2.79
10	5'-7'	25.99	25.51	41.26	4.89	1.63	0.72
12	7'-10'	17.92	14.29	46.58	13.53	4.94	2.72
15	10'-15'	11.64	23.82	59.47	3.72	0.86	0.49
17	15'-20'	21.90	35.48	39.54	1.84	0.76	0.47
18	15'-20'	21.04	29.76	42.36	4.28	1.74	0.82
21	20'-25'	26.91	44.43	25.09	1.70	1.31	0.54
22	25'-30'	6.47	18.76	70.40	2.99	0.84	0.54
27	30'-35'	6.82	11.51	62.23	15.22	3.36	0.85
28	35'-40'	1.19	2.39	46.81	35.81	10.60	3.20

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[1] See Table C-12 for sample numbers.

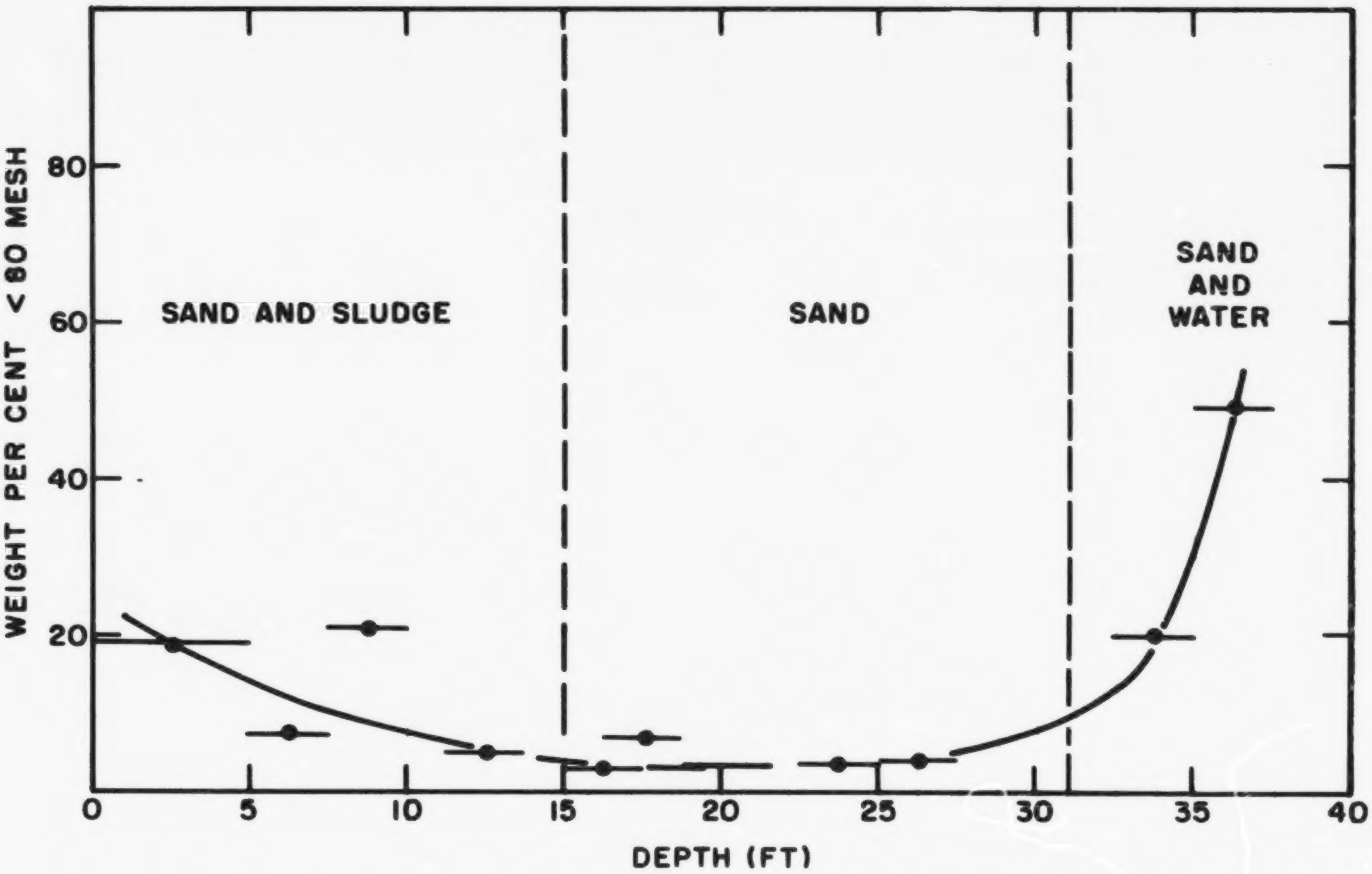

Fig. C-14: Vertical distribution of percentage of particles < 80 mesh at test hole #17.

Table C-14

Chromium Content of Sieved Fractions of Samples from Test Hole #17

Sample	Depth (ft)	Cr Content (ppm) in Sample Fraction Whole Sample	200> - >325	<325
22	25-30	14.1	85	115
27	30-35	99.0	240	380
38	35-40	26.4	25	60

Total Amount and Per Cent of Total Cr in Sieved Fraction(1)

Sample	Depth (ft)	Total Cr per mg	% of Total 200> - >325	<325
22	25-30	14.1	5.0	4.3
27	30-35	99.0	8.1	2.0
28	35-40	26.4	10.2	6.7

---

(1) See Table C-13 for weight per cent of each sieve fraction.

were obtained by allowing wet sand collected at or near the bottom of the test hole to settle; the supernatant water (containing some fine particles) was analyzed for Cr both before and after filtration. Results of such analyses are shown in Table C-15. The amount of dissolved Cr is negligible ($\sim$ 1 ppb), although particulate Cr is obviously in intimate contact with this liquid.

Further confirmation of the insolubility of Cr containing compounds in these historical sludge deposits was provided by leaching tests carried out with samples from test hole #17. Portions (0.4 g) of various soil samples (not dried) were placed in 30 ml of distilled water for six days at room temperature (about 25°C). The liquid was then filtered through a 0.45 μm filter, made up to a fixed volume (50 ml), and analyzed for Cr. The analyses, given in Table C-16, showed no detectable Cr in solution.

Analyses for other constituents, besides Cr, were also carried out. Results for sodium are given in Table C-12; for chloride and organics (COD) in Table C-17. To place these results in perspective, similar analyses (for Cr, Na, Cl^- and COD) were carried out with samples obtained at a nearby site which was free of sludge. The chloride analysis was carried out by extracting 10 g of sample with 40 cc of distilled water at 100°C for 1 hr. The samples were then filtered and washed, the filtrate was made up to 100 cc and analyzed for Cl^-. COD analyses were carried out by standard techniques. Results are given in Table C-18.

The distribution of all these constituents (sodium, chloride and organics) is similar to that for Cr. Concentrations are high in the sludge deposit but decrease very quickly in the layers of sand below the sludge. In all cases, there is a clear increase at sample 27 which coincides with the increase in Cr. For example, the COD values increase from about 1.5 mg/g to 2.5 mg/g; similar increases were found for chloride and sodium. These distributions are consistent with particles of sludge having been carried downwards with some accumulation at the water table. They cannot be reconciled with a mechanism involving leaching and precipitation, since these constituents (chromium, sodium and chloride, and organics) have widely varying solubilities.

Table C-15

Analysis of Supernatant Liquid Obtained by Allowing Wet Sand to Settle from Mixed Sand-Water Samples of Test Hole #17(1)

Sample No.	Cr (ppm)	Na (ppm)	Comments
28	0.001	-	Unfiltered, settled
28	0.27	17.0	Unfiltered, shaken
28	0.001	15.2	Filtered
29	0.001	13.5	Filtered
30	0.001	14.9	Filtered

---

(1) See Fig. C-5 for location of test hole #17.

Table C-16

Chromium Extraction from Soil Samples(1) of Test Hole #17

Sample No.	Depth (ft)	Cr Content of Soil (ppm of dry soil)	Extracted Cr(2) (ppm)
8	0-5	1,200	<0.02
11	5-7.5	3,530	<0.02
16	10-15	27.6	<0.02
19	15-20	50.3	<0.02
20	20-25	16.9	<0.02
24	25-30	9.5	<0.02
26	30-35	34.3	<0.02
29	35-50	15.8	<0.02

---

(1) Extraction of 0.40g of soil (not dried) with 30 ml of doubly distilled water at room temperature (∿25°C) for six days. Solutions filtered through 0.45 μm HA Millipore filter and made up to 50 ml with distilled water.

(2) Below analytical limit of procedure.

Table C-17

Soils Analysis for Chloride and COD of Samples from Test Hole #17

Test Hole #17

Sample	Depth (ft)	H_2O (wt %)	Chloride (mg/g dry wt)	COD (mg/g dry wt)
8	0-5	18.0	0.040	24.1
10	5-7	24.4	0.20	142.2
12	7-10	23.9	0.30	146.5
15	10-15	3.65	0.037	7.21
18	15-20	3.42	0.019	1.46
21	20-25	1.40	0.028	1.62
23	25-30	1.71	0.018	1.57
25	30-35	15.6	0.016	1.29
27	30-35	12.7	0.034	2.51
29	35-40	17.2	0.015	1.62

Table C-18

Sieve and Chemical Analyses of Soils Free from Sludge

A. Sieve Analysis

		Weight Per Cent					
Sample	Depth (ft)	Mesh >10	>20	>80	>200	>325	<325
3	0–5	1.67	25.59	71.11	1.17	0.31	0.15
5	5–10	1.09	18.69	77.77	1.87	0.33	0.24

B. Soils Analyses for Cr and Sodium

Sample	Depth (ft)	H_2O (wt %)	Cr (ppm)	Na (ppm)	Chloride (ppm)	COD (mg/g dry wt)
1		1.13	7.41	75.3	-	-
2	0–5	2.52	12.8	73.0	20	1.50
3		2.32	8.04	71.7	-	-
4		2.23	7.02	76.5	-	-
5	5–10	1.97	18.2	77.1	22	1.49
6		1.63	7.71	94.4	-	-

(b) Cation Exchange Capacity

The cation exchange capacity (CEC) is the sum of exchangeable cations of a soil. Many methods have been proposed and used for determining CEC. Currently, most techniques involve saturating the exchange complexes with a given cation and then determining the total adsorbed cation analytically. The method used here was the alkaline sodium acetate (pH 8.2).

Values of cation exchange capacity of samples at various depths are given in Table C-19. Values in the range of a few mequiv/100 g are consistent with the nature and particle size of the soils in question.

5. Chemical Analyses of Groundwater

(a) Procedures

Analyses of groundwater for total and dissolved Cr, sodium, calcium, nitrate and Kjeldahl nitrogen, chloride, and COD were carried out using standard analytical techniques (see Table C-20). In all cases, samples were taken after 1 hr of pumping at rates of 15 to 50 gpm and should be representative of groundwater quality in the vicinity of the well. Well numbers correspond to those used previously; the location of the wells is shown in Fig. C-5.

Samples were stored in polyethylene containers, except for samples to be analyzed for TOC (total organic carbon) where glass containers were used. Groundwater samples were collected generally during the month of December, 1976 and had to be warmed to avoid freezing during transport for analysis. They were refrigerated at 40°F at the laboratory.

Samples containing low levels of Cr may loose Cr by adsorption on container walls. Although such losses, expected for glass containers, were not anticipated for the polyethylene containers used here, the extent of possible losses of Cr during storage was ascertained by preparing solutions with known concentrations of Cr, storing them in similar polyethylene containers used for sample collection, and periodically analyzing them for Cr. No detectable loss of Cr was observed. In

Table C-19

Cation Exchange Capacity of Soils at Test Hole #17 and Nearby

A. Test Hole #17

Sample	Depth (ft)	CEC(1) (mequiv/100g)
23	25-30	2.2
30	35-40	4.1

B. Site Near Test Hole #17

Sample	Depth (ft)	CEC(1) (mequiv/100g)
2	0-5	1.9

---

(1) Determined by the sodium acetate method at pH 8.2.

Table C-20

Groundwater Analyses(1)

Well Number:	#7		#8	#10	#13		#14	#15
Groundwater Table (ft):	12.0		9.2	7.0	22.1		14.5	14.5
Groundwater Sample (ft):	35-45	91-101	67-77	67-77	30-40	55-65	45-55	45-55
Total Cr (ppb)	<0.5	0.5	2.0	<0.5	<0.5	<0.5	2.0	1.0
Dissolved Cr (ppb)(2)	<0.5	<0.5	0.5	<0.5	<0.5	<0.5	<0.5	<0.5
Sodium (ppm)	17.1	45.6	6.4	7.5	2.3	3.5	5.8	6.1
Calcium (ppm)	31.4	37.9	32.5	23.1	7.3	9.9	17.3	17.6
Chloride (ppm)	25.7	67.3	15.0	17.4	1.0	3.2	9.4	8.7
Nitrate Nitrogen (ppm)	4.10	3.80	0.14	1.15	1.64	0.37	0.64	0.66
Kjeldhal Nitrogen (ppm)	0.85	1.14	0.26	1.89	2.95	2.69	4.65	4.12
COD (mg/ℓ)(3)	10.7	<5.0	1.3	<5.0	<5.0	<5.0	<5.0	<5.0

---

(1) Samples taken at least 1 hr after pumping at rates of 15 to 50 gpm.

(2) "Dissolved" Cr is the amount of Cr in the filtrate through a 0.45 μ filter.

(3) Where "less than" is noted, the COD content was equal or less than the blank.

particular, solutions containing 25 and 50 ppb showed no detectable change (within the precision of the analysis) after storage for 100 days.

(b) Results

The range of variation of analyses with sampling time and with time of pumping are illustrated in Table C-21. Table C-22 illustrates the precision of Cr analyses at the low levels encountered here. Results obtained and reported previously by Whitman & Howard are shown in Table C-23.

All of these results are within normal values for groundwater; none of the values for the various constituents exceed drinking water standards. However, when all of them are considered, it is clear that groundwater quality at well #7 is significantly lower than the average groundwater quality in the area, particularly at depths near the bottom of the groundwater table. Results of groundwater analyses are shown in Table C-20.

Well #7 is about 1500 ft downstream from the old deposits of sludge at the Lawrence site and about 400 ft downstream from the Norway dump across the river. It is highly probable that the decreased water quality at well #7 is a result of leachate from the Norway dump. This is suggested by the relative distances (given above) and by the fact that groundwater quality between the old sludge deposits and well #7 shows no indication of deterioration (see Table C-23).

Analysis of groundwater directly beneath the old sludge deposits was carried out by drilling a test well (#18) at essentially the same place as test hole #17. The groundwater table was at 30.5 ft and refusal was at 50.0 ft. Samples were withdrawn (after 1 hr of pumping) from 35-40 ft and 45-50 ft and analyzed with results given in Table C-24.

As shown in Fig. C-12, the groundwater elevation in this area is higher than groundwater elevations nearer the river (north and south from the old sludge site) by about 40 ft. Groundwater below the old sludge deposits must originate from local infiltration and, probably, from drainage from the hills rising steeply on the far side of East Oxford

Table C-21

Groundwater Analyses

Sample[1]	Well #8 A	Well #8 B	Well #13 A	Well #13 B	Well #14 A	Well #14 B
Total Cr (ppb)	2.0	2.0	< 0.5	< 0.5	2.0	2.0
Dissolved Cr (ppb)	0.5	0.5	< 0.5	< 0.5	< 0.5	< 0.5
Sodium (ppm)	6.2	6.6	3.5	3.4	6.3	5.4
Calcium (ppm)	31.7	33.0	9.8	10.3	18.1	16.5
Nitrate Nitrogen (ppm)	0.14	0.13	0.43	0.30	0.69	0.60

---

(1) Samples taken as follows:

Well #8:	Sample A after 1 hr pumping at 15 ppm from 67-77 ft Sample B - as for A, 1 week later
Well #13:	Sample A after 1 hr pumping at 10 gpm from 55-65 ft Sample B - as for A, but after 3 hrs of pumping
Well #14:	Sample A after 1 hr pumping at 50 gpm from 45-55 ft Sample B - as for A, but after 3 hrs of pumping

Table C-22

Cr Analyses of Groundwater Samples(1)

Sample	Total Cr (ppb)	Dissolved Cr (ppb)
Well #7, 35'-45'	0.0 + 0.2	0.0 + 0.2
Well #7, 91'-101'	0.5 ± 0.2	0.0 + 0.2
Well #8, 67'-77'	1.7 ± 0.8	0.4 ± 0.2
Well #8, 67'-77'	1.3 ± 0.5	0.3 ± 0.3
Well #10, 67'-77'	0.0 + 0.2	-
Well #13, 30'-40'	< 0.5	-
Well #13, 55'-65'	< 0.5	-
Well #13, 55'-65'	< 0.5	-
Well #14, 45'-55'	2.0 ± 0.5	< 0.5
Well #14, 45'-55'	2.0 ± 0.5	< 0.5
Well #15, 45'-55'	1.0 ± 0.5	< 0.5

---

(1) Where limits are given, multiple analyses (up to 12) were run; the limits are 95% confidence limits.

Table C-23

Groundwater Analysis from Well #3 of Whitman and Howard[1]

	Depth in Water Table	
	5 ft	15 ft
pH (15°C)	7.0	7.0
BOD (ppm)	8.0	5.0
COD (ppm)	<10.0	<10.0
TDS (ppm)	39.0	41.0
Manganese (ppm)	0.20	0.13
Magnesium (ppm)	0.90	1.0
Copper (ppm)	0.19	0.19
Zinc (ppm)	0.85	0.25
Calcium (ppm)	11.0	10.0
Iron (ppm)	0.31	0.38
Nickel (ppm)	<0.1	<0.1
Chloride (ppm)	1.5	1.5
Phosphate (ppm)	0.25	0.55
Nitrate (ppm)	0.095	0.66
Nitrite (ppm)	0.005	0.21
Ammonia (ppm)	1.8	2.6

---

(1) "Site Evaluation Report - Sludge Landfill, Paris Utility District, South Paris, Maine" Whitman and Howard Inc., Boston, Ma., January 1975. Test well #3 was near the pond, downstream by about 350 ft from old sludge deposit site. The water table was at 21 feet.

Table C-24

Groundwater Analyses at Test Well #18

Top of Water Table: 30.5 ft
Refusal: 50.0 ft

	Groundwater Depth (ft)	
	35-40	45-50
pH	6.2	6.3
Conductivity (μmho/cm)	123.0	219.0
E_h (volts)	0.51	0.50
Sodium, ppm	3.7	12.0
Calcium, ppm	10.3	19.5
Manganese, ppm	0.59	0.29
Magnesium, ppm	1.2	4.5
Iron, ppm	0.55	1.0
Total Chromium, ppm	<0.02	<0.02
Chloride, ppm	11.9	12.9
Nitrate, ppm as N	4.3	2.8
Nitrite, ppm as N	0.03	0.23
TKN, ppm as N	2.2	0.7
Ammonia, ppm as N	0.02	0.03
Total Phosphorus, ppm	1.4	<0.5
COD, mg/ℓ	3.8	22.8
TOC, mg/ℓ	2.0	9.0

Street. Leachate from the site enters this groundwater and would generally flow towards the river (towards the north) given the steep hydrological gradient in this direction.

The results in Table C-24 show no significant impairment of water quality beneath the old sludge deposits. In interpreting these results, it should be noted that the groundwater water table is unconfined and has a total thickness of about 10 ft. Since flow to a partially screened well in this formation has a significant vertical component, the samples withdrawn from the first 5 to 10 ft (screen at 35-40 ft), are representative of groundwater in about the top half of the table and samples withdrawn from the last 15-20 ft are representative of the bottom half. In both cases, water quality has not deteriorated significantly. However, comparison of the two sets of results shows that the bottom layers have accumulated somewhat higher concentrations of constituents expected from the sludge (see, for example, sodium and calcium). Nitrogen, which is subject to bacterial action, is higher in the top half, particularly as nitrate nitrogen. The distribution of sodium is consistent with a somewhat larger volume of groundwater flow in the top layers. Because of such flow, long-term accumulation would be expected to be less pronounced in the top layers than near the bottom.

6. Uptake of Chromium by Plants

Analysis of vegetation for trace elements provides an indication of the concentration of these elements in the surrounding soil. In the case of Cr, there does not appear to be any preferential uptake by plants. However, increased Cr content in the soil is reflected in increased Cr content in plants.

Leaf samples were collected from two species, oak and white pine. The first is relatively deep-rooted while the latter has shallow roots. The leaves were ashed and the ash analyzed for total Cr by atomic absorption. Sampling locations are shown in Fig. C-15. Results of the analyses are shown in Tables C-25 and C-26.

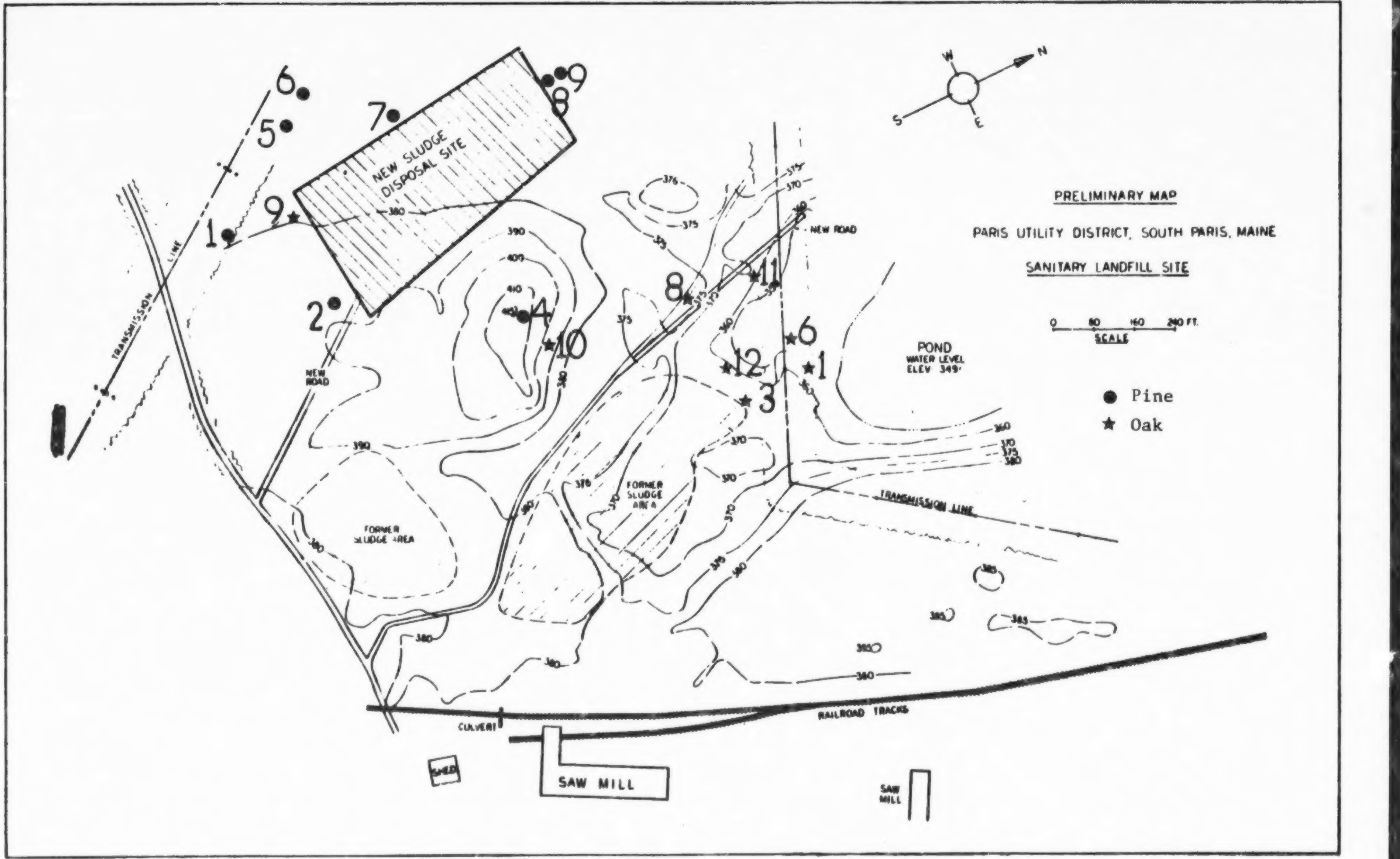
PRELIMINARY MAP
PARIS UTILITY DISTRICT, SOUTH PARIS, MAINE
SANITARY LANDFILL SITE
0 80 160 240 FT.
SCALE
W
N
S
E
● Pine
★ Oak
NEW SLUDGE DISPOSAL SITE
FORMER SLUDGE AREA
FORMER SLUDGE AREA
NEW ROAD
NEW ROAD
TRANSMISSION LINE
TRANSMISSION LINE
POND
WATER LEVEL ELEV 349'
RAILROAD TRACKS
CULVERT
SHED
SAW MILL
SAW MILL
1
2
4
5
6
7
8
9
1
3
6
8
9
10
11
12
360
370
375
380
390
400
410

Fig. C-15: Locations of sampling sites for pine and oak leaves.

Table C-25

Analyses of Oak Leaves for Chromium

Location	Total Chromium in Leaves (ppm of ashed leaf)
1	69
2	234
3	292
4	97
5	57
6	256
7	181
8	44
9	91
10	29
11	45
12	63

Note: Background content of oak leaves (Sabbath Day Pond) is about 40 ppm.

Locations 2, 4, 5 and 7 were by the settling lagoons (outside the area shown in Fig. C-15).

Table C-26

Analyses of White Pine Needles for Chromium

Location	Total Chromium in Needles (ppm of ashed needles)
1	40
2	88
3	(not obtained)
4	190
5	47
6	43
7	159
8	131
9	116

The Cr content of leaves of both oak and white pine at the A. C. Lawrence site exceeds in several instances the background levels in the general area. The approximate (schematic) gradients of Cr concentration in leaves indicated in Fig. C-16, though based on limited data, are nevertheless suggestive of surface dispersion (presumably by runoff) of Cr. Data at the old sludge deposit area suggest that runoff moves northward (towards the pond). There appears to be little surface dispersion of Cr either east or west from the site. The data obtained at the new (currently utilized) disposal site suggest that surface dispersion of Cr is also northward while movement of Cr west and southwest is slow as indicated by the relatively steep Cr gradient.

7. Assessment of Environmental Impacts of the A. C. Lawrence Site

Sludge dumping at the A. C. Lawrence site over the last 15 years has not led to significant or lasting effects on groundwater quality, in spite of the relatively haphazard ways in which sludge was deposited on the site. Absence of adverse impacts is attributed to the nature of the sludge and the hydrology of the area.

Characteristics of the sludge that may have led to a low leachate load include a high content of relatively insoluble inorganic material ($CaCO_3$ and $Cr(OH)_3$); characteristics of the site that may have led to a low concentration of pollutants in the groundwater include high permeability of sediments, relatively large groundwater flows, and steep hydrologic gradients.

The high permeability of sediments implies relatively rapid movement of infiltrating rainwater and hence a limited contact time between sludge and rainwater. Steep hydrologic gradients at the site imply high groundwater velocities and hence relatively rapid mixing of water which has come in contact with the sludge with the general groundwater in the area. Furthermore, the relatively large flows of groundwater lead to dilution of material leached from the sludge.

A major constituent of concern, namely chromium, appears to be essentially insoluble under local conditions and its concentration in the groundwater is negligible.

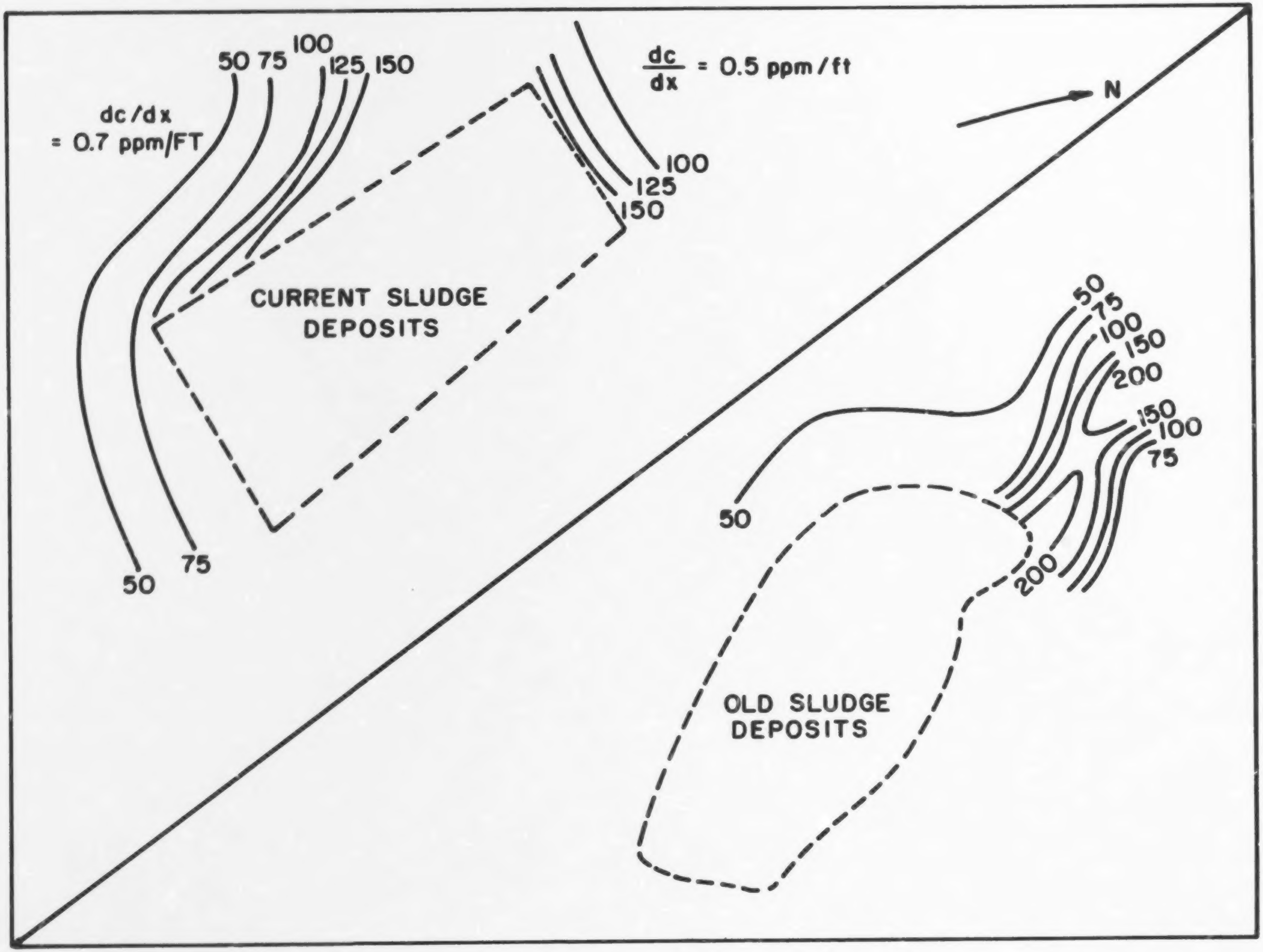
50
75
100
125
150
dc/dx
= 0.7 ppm/FT
$\frac{dc}{dx}$ = 0.5 ppm/ft
N
100
125
150
CURRENT SLUDGE DEPOSITS
50
75
50
75
100
150
200
150
100
75
50
200
OLD SLUDGE DEPOSITS

Fig. C-16: Surface dispersion of Cr as determined by uptake by pine and oak.

It should be noted that historical sludge deposits were not dewatered. Current sludge is expected to be considerably less permeable to water than sludge sediments deposited at the A. C. Lawrence site in the past. Accordingly, considerably less leachate is expected to be generated from current sludge.

APPENDIX D

THE RYERSON HILL SITE

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APPENDIX D

THE RYERSON HILL SITE

1. Introduction

This section reviews the suitability of the Ryerson Hill site for sludge disposal. The local geologic and soil conditions are described first. The section on regional geology in the preceding appendix (Appendix C) should be consulted for a broader view of the geologic setting.

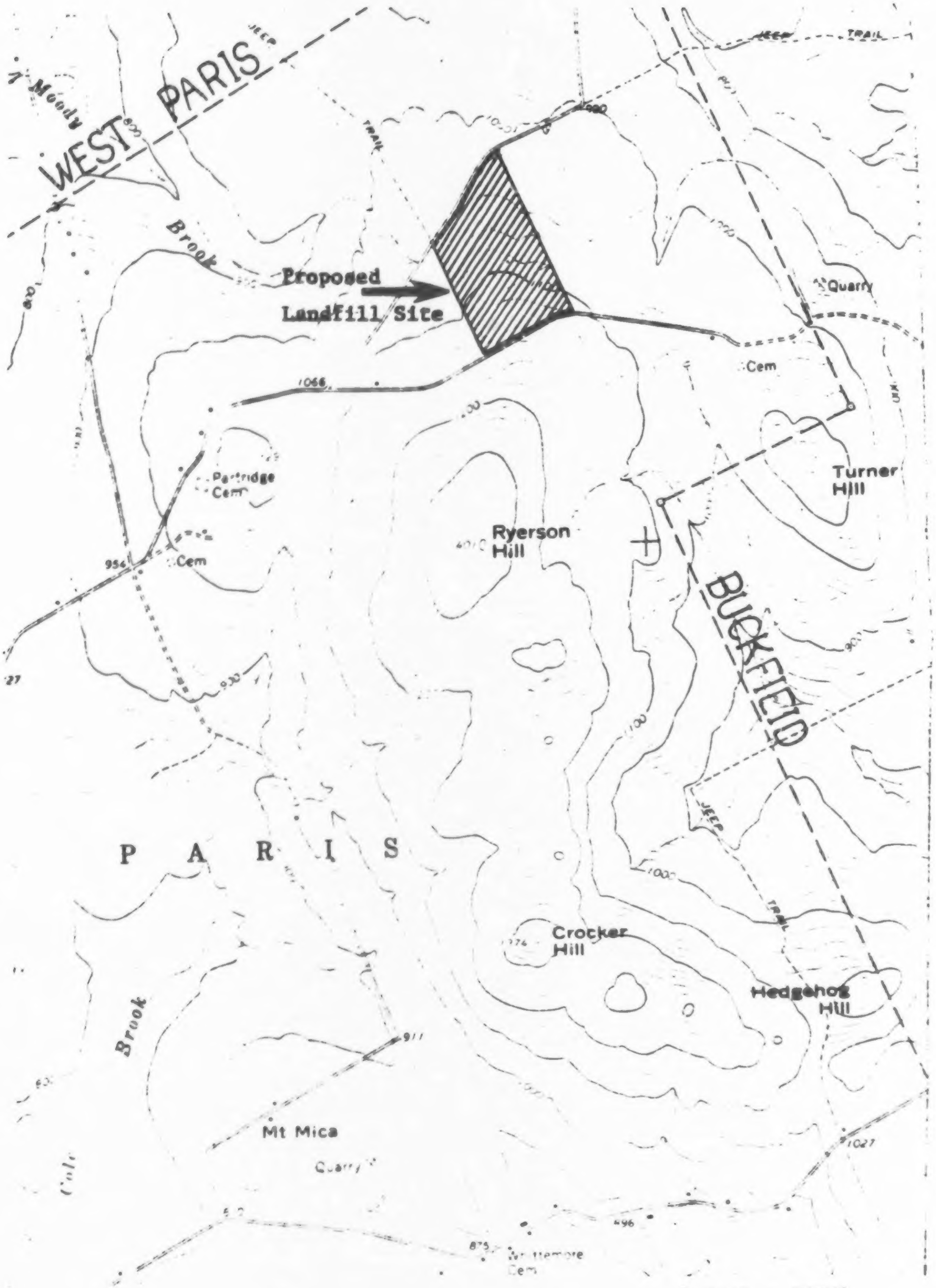
The essential features of the proposed landfill design for the Ryerson Hill site are reviewed and technical problems presented by the nature of the site and landfill design are detailed. Specialized hydrologic questions relevant to disposal of sludge at this site are discussed with particular reference to items introduced at the public hearing.

The overall analysis suggests that the site can probably be operated in an environmentally acceptable manner. However, considerable uncertainty will remain until actual experience demonstrates that such operation is indeed possible. Thus, utilization of this site would entail at least a financial risk.

2. Local Geology and Physiographic Characteristics of the Ryerson Hill Site

The prospective sludge disposal site at Ryerson Hill in northeast Paris is situated as shown in Fig. D-1. The proposed site, covering approximately 52 acres, is at an elevation of about 1140 ft at its southern boundary and 1020 ft at its northern boundary. The topography slopes at about 5% to the North and somewhat more gently to the East and West.

The Ryerson Hill terrain consists of glaciated bedrock with a discontinuous shallow overburden of till which has subsequently developed


WEST PARIS
Moody
Brook
Proposed Landfill Site
Quarry
Cem
Turner Hill
Partridge Cem
Ryerson Hill
BUCKFIELD
PARIS
Crocker Hill
Hedgehog Hill
Brook
Cole
Mt Mica
Quarry
Whittemore Cem
JEEP TRAIL
TRAIL
1066
1000
956
1027
911

1 inch = 2000'

Fig. D-1: Location of proposed Ryerson Hill landfill site.

a soil profile including a permeable upper soil profile (solum) extending to approximately 2.5-3 ft. depth and a fragipan substratum which extends to bedrock, typically at approximately 12 ft. depth. The fragipan is quite compact in partial consequence of the effect of overriding glacial ice. This substratum contains fines (<200 mesh) ranging from 20 to 65 percent by weight. Accordingly, the fragipan has much lower permeability than the solum.

The contrast in permeability leads to the existence of a perched groundwater table in the upper soil profile with a seasonal high water table within 18 inches of the surface. Groundwater is restricted to a shallow depth by the fragipan permeability barrier. Groundwater may also be confined beneath the fragipan and may be held in the joint systems of the bedrock. Figure D-2 is a hypothetical cross section indicating the surficial geologic relationships at Ryerson Hill.

Penetration of the fragipan by bedrock outcrops or artificial means may lead to springs discharging through the fragipan. Springs, probably of this origin, occur on and near the site. The fragipan-spring association is an important concern from an engineering standpoint where these soils (specifically the Ridgebury and Peru soils at this site) are concerned. Agricultural experience in the locale provides examples of engineering problems connected with springs in these fragipan soils. The likelihood that a bedrock outcrop or other penetration of the fragipan will be associated with the occurrence of an active spring depends on factors such as the frequency and geometry of joints in the bedrock, which can collectively provide a groundwater reservoir, as well as the height of the local piezometric surface.

The Ryerson Hill site is in the drainage path of an areally extensive watershed extending south toward the crest of Ryerson Hill. Furthermore, the perched groundwater is confined to a shallow depth in the upper soil profile. These factors are consistent with a large volume of groundwater discharge above the fragipan at the Ryerson Hill site.

Ryerson Hill is a watershed area for at least three streams (Moody, Darnit and Cole Brooks). Also, there are several ponds with 1/2 mile of

HYPOTHETICAL GEOLOGIC CROSS SECTION FOR RYERSON HILL SITE

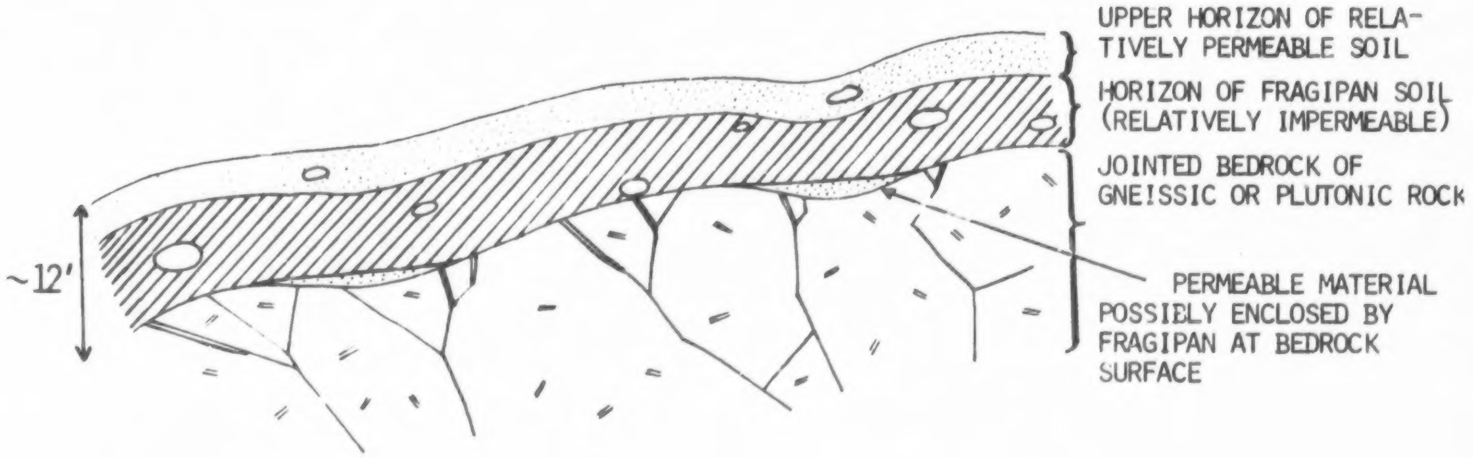

UPPER HORIZON OF RELATIVELY PERMEABLE SOIL
HORIZON OF FRAGIPAN SOIL (RELATIVELY IMPERMEABLE)
JOINTED BEDROCK OF GNEISSIC OR PLUTONIC ROCK
PERMEABLE MATERIAL POSSIBLY ENCLOSED BY FRAGIPAN AT BEDROCK SURFACE
~12'

Fig. D-2: Hypothetical geologic cross section for Ryerson Hill site.

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the proposed site. There are no classified bodies of water within 300 ft of the site. There is one adjacent well. One spring and at least two intermittent streams have been identified on the site.

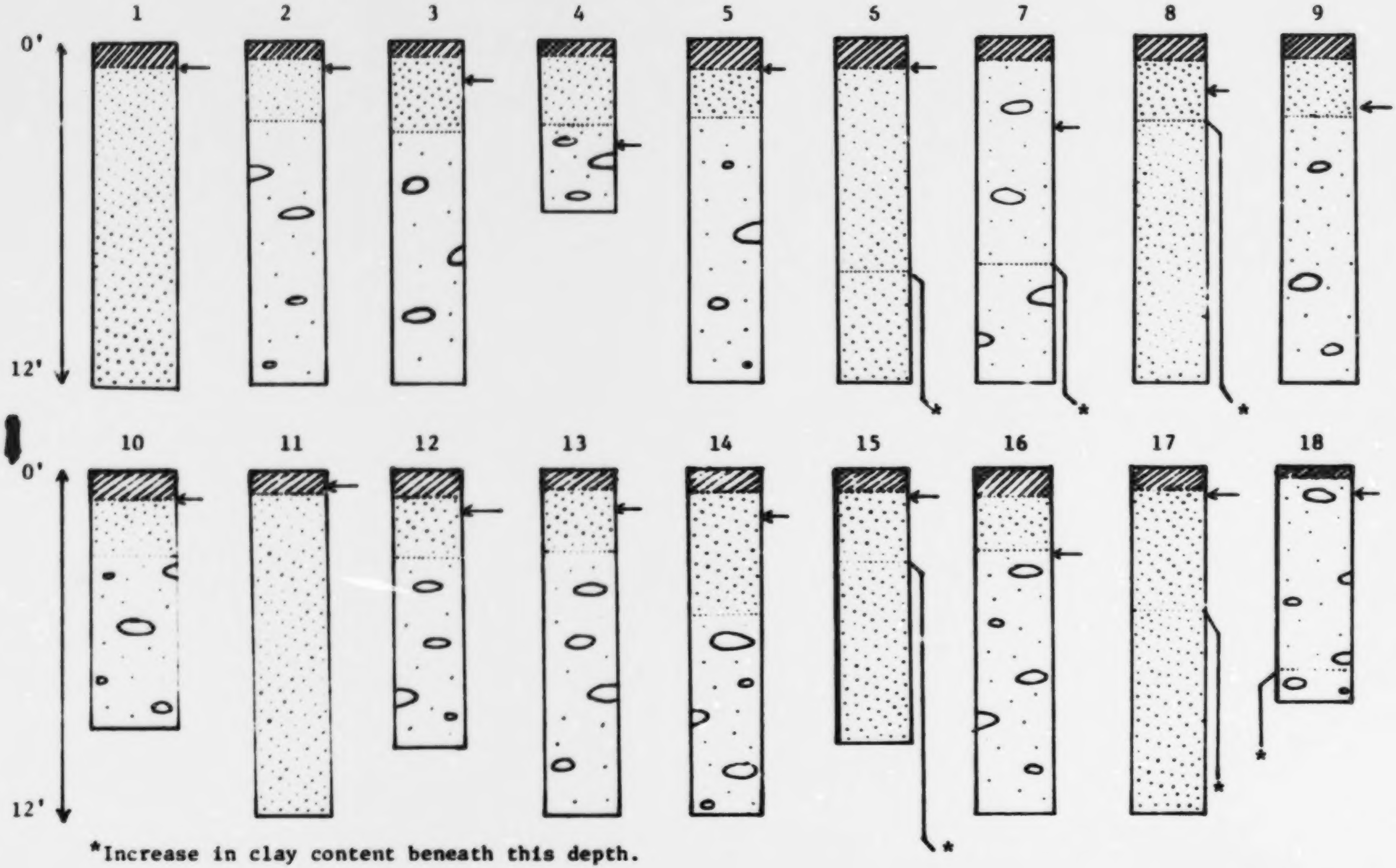
Figure D-3 presents geologic data from augered test holes at the Ryerson Hill site (see "Design Report and Operational Manual for Sludge Landfill, Paris Utility District, South Paris, Maine" by Whitman and Howard, June 1975). Locations of the test holes are indicated in Fig. D-4. These holes were drilled to a maximum depth of 12 ft; shallower holes reached refusal at depths indicated in the test hole logs. It should be noted that fragipan probably occurs in all the test holes. However, in Fig. D-3, till has been indicated only where the test hole logs reported till specifically. In the absence of any specific designation in the test hole logs, the geologic profiles indicate the lithologic character only.

3. Soil Survey Data

The results of a medium intensity soil survey including the Ryerson Hill site are available from the USDA Soil Conservation Service. The areal soils distribution given in Fig. D-5 indicates that Ridgebury and Peru soils are prevalent at the proposed site.

The Ridgebury soil has been described as a poorly drained sandy soil with fragipan. The soil type occurs on level to moderately sloped (0-5%) areas principally on upland hills and ridges underlain by granitic, gneissic and schistose glacial till. Ridgebury soil occurs mostly in southern Maine. The soil consists of a dark surface layer of fine sandy loam 2 to 10 inches thick. This is underlain by an olive-gray fine sandy loam subsoil. A firm compact fragipan occurs at from 10-25 inches depth. Coarse fragments and stones comprise from 5 to 35 percent of the soil volume. Depth to bedrock is greater than 4 ft. The surface may be quite dry in summer but is often saturated in the remaining seasons by a perched groundwater table. Permeability in the upper soil is moderate to high but is low in the fragipan. The soil has high susceptibility to frost action, good compactibility and slow to medium runoff characteristics.

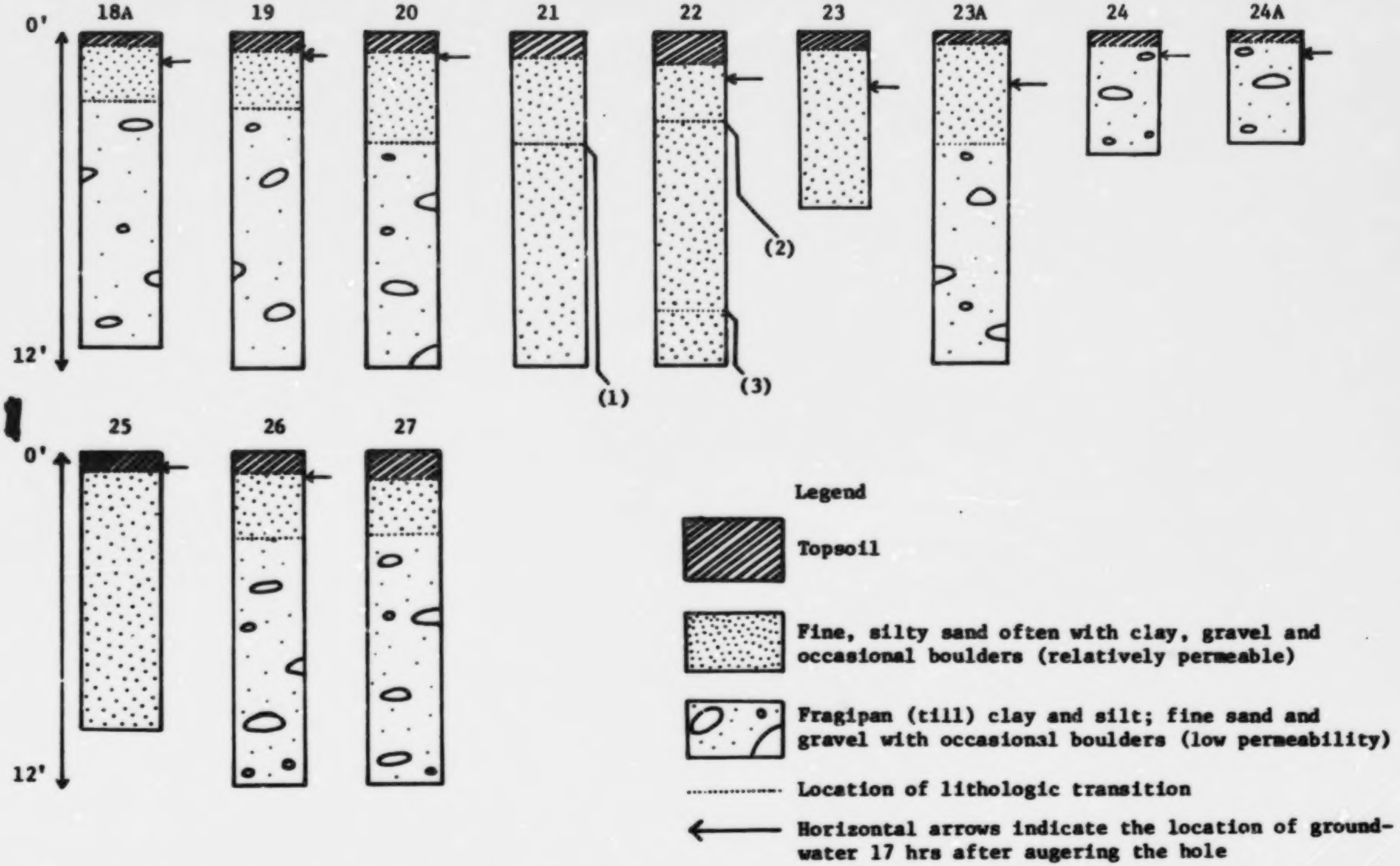
D-6



1
2
3
4
5
6
7
8
9
0'
12'
*
*
*
10
11
12
13
14
15
16
17
18
0'
12'
*
*
*

*Increase in clay content beneath this depth.

Fig. D-3: Geologic profiles obtained from augered test holes.



Legend

▨ Topsoil

░ Fine, silty sand often with clay, gravel and occasional boulders (relatively permeable)

○ Fragipan (till) clay and silt; fine sand and gravel with occasional boulders (low permeability)

········ Location of lithologic transition

← Horizontal arrows indicate the location of groundwater 17 hrs after augering the hole

(1) Increase in gravel content beneath this depth.
(2) Increase in clay content beneath this depth.
(3) Increase in mica content beneath this depth.

D7

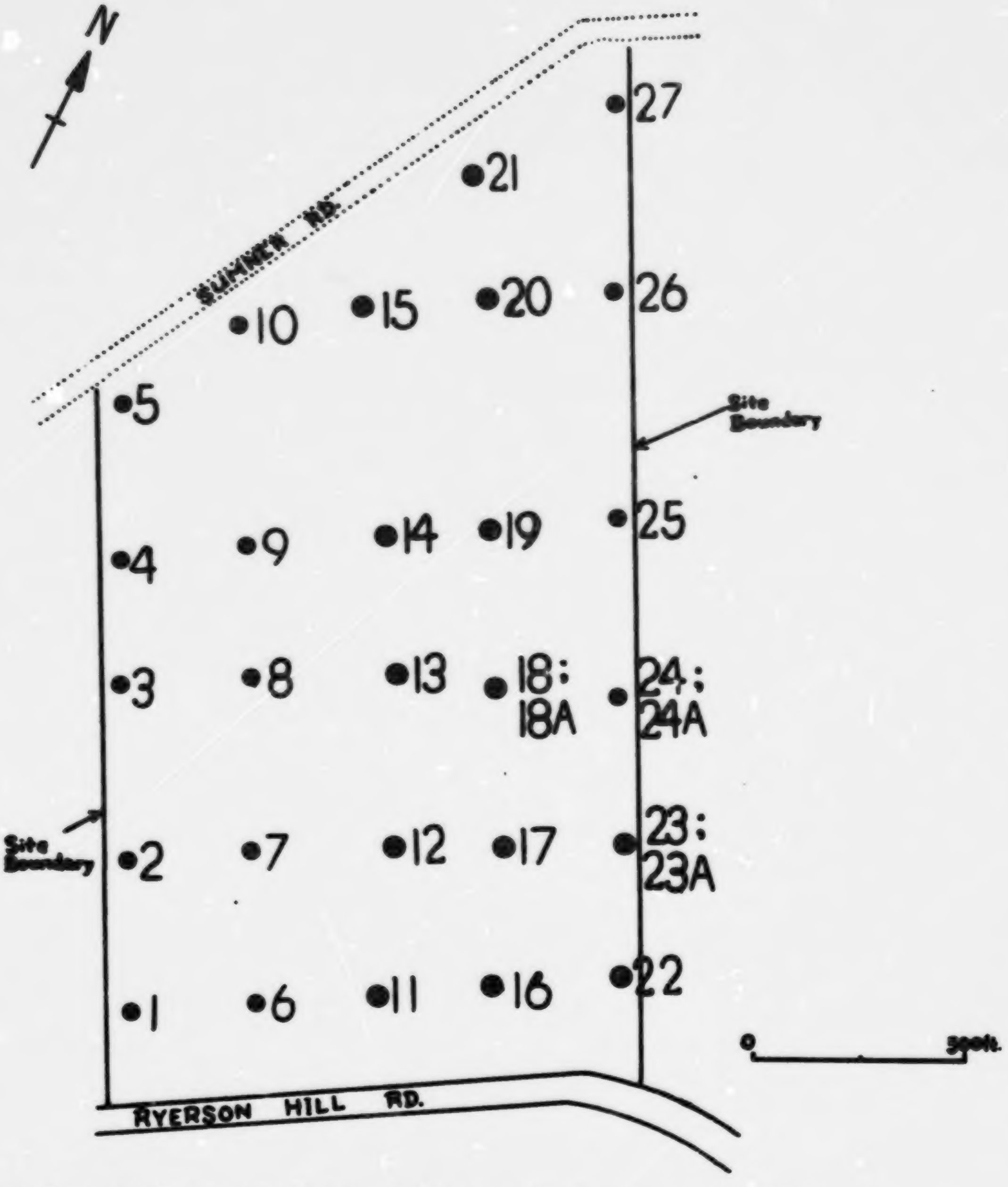

N
SUMNER RD.
27
21
10
15
20
26
5
Site Boundary
4
9
14
19
25
3
8
13
18; 18A
24; 24A
Site Boundary
2
7
12
17
23; 23A
1
6
11
16
22
0
500ft.
RYERSON HILL RD.

Fig. D-4: Location of augered test holes at the Ryerson Hill site.

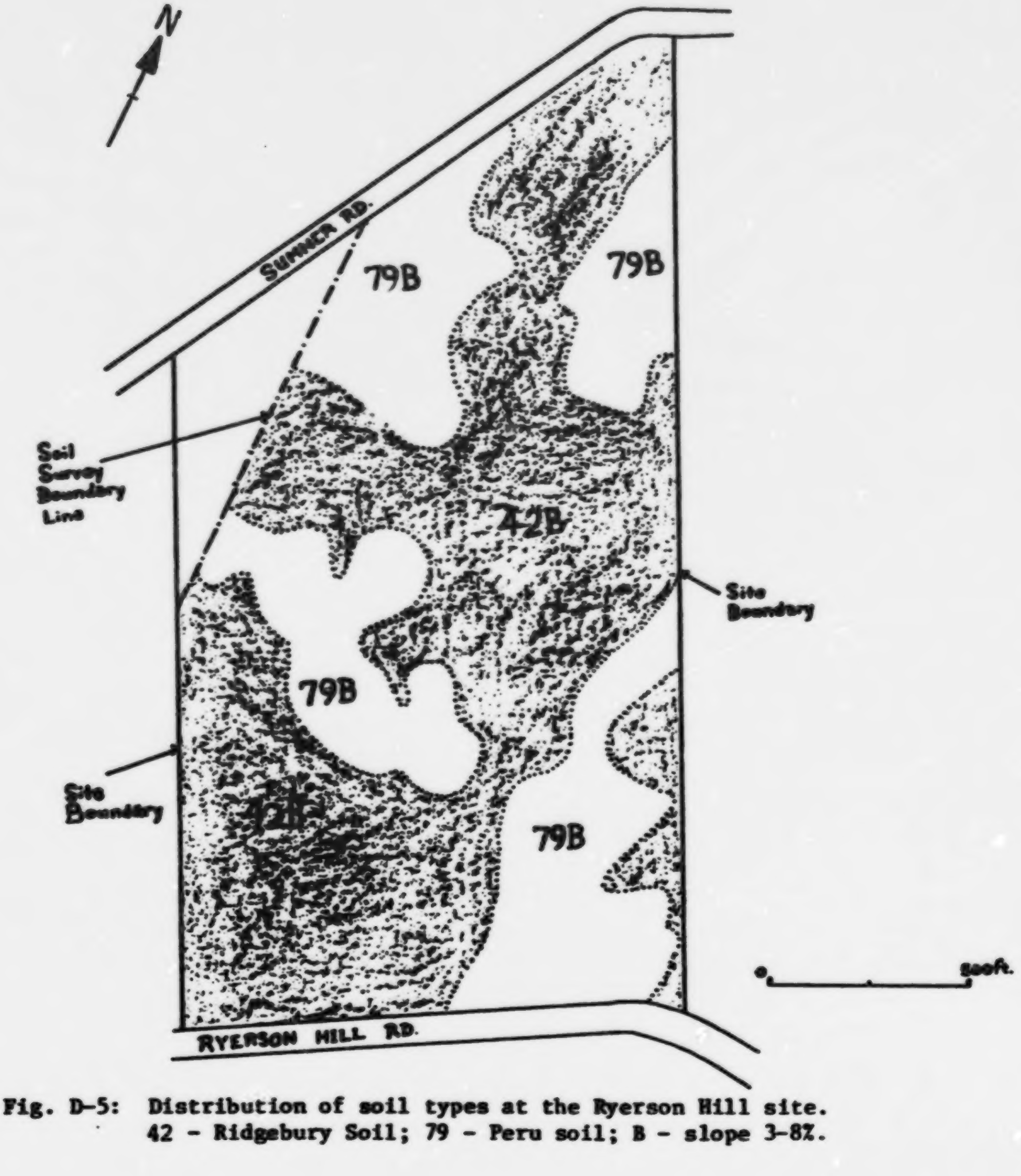

N
SUMNER RD.
79B
79B
Soil
Survey
Boundary
Line
42B
Site
Boundary
79B
Site
Boundary
42B
79B
0
500ft.
RYERSON HILL RD.

Fig. D-5: Distribution of soil types at the Ryerson Hill site. 42 - Ridgebury Soil; 79 - Peru soil; B - slope 3-8%.

The Ridgebury soil is difficult to work due to the saturated soil conditions and stoniness.

The Peru soil has been described as a moderately well-drained fine sandy soil occurring on nearly level to moderately steep (0 to 25% slope) on glaciated upland areas. Slopes are generally between 3 and 8%. The soil consists of a dark grayish-brown fine sandy loam surface layer and a dark reddish-brown fine sandy loam upper subsoil. The lower subsoil is an olive-brown fine sand loam. Fragipan occurs at from 18 to 34 inches depth. Coarse fragments and stones comprise from 0-30% of the soil by volume. Depth to bedrock is greater than 4 ft from the surface. Permeability is moderate in the upper soil and low in the fragipan. Surface runoff is slow to rapid depending on slope. Frost susceptibility is moderate. The soil is difficult to work due to saturated soil conditions and stoniness.

Table D-1 below gives physical and engineering properties of the Ridgebury and Peru soils. This data is not site specific to Ryerson Hill but reports general characteristics of these soils.

4. Engineering Aspects of the Design for Sludge Landfill at Ryerson Hill

Partially in consideration of the DEP regulation that solid waste materials be deposited 5 feet or more above the groundwater table, the design provides for removal of the perched groundwater from the site so that the groundwater table would be at least 5 ft below the waste (see "Design Report and Operation Manual for Sludge Landfill, Paris Utility District, South Paris, Maine" by Whitman and Howard, June 1975).

In order to drain the perched water table and prevent surface runoff and subsurface flow from entering the site, groundwater and surface runoff would be diverted and redirected by a network of underdrain trenches and surface ditches. It was proposed to install an underdrain trench on the uphill (south) side and continue it down both the east and west margins of the fill area. Figure D-6 shows the design cross section of this trench. The perforated pipe at the bottom would emerge at ground surface at the lower end (north) of the site and water would discharge from there downslope.

Table D-1

Physical and Engineering Properties of Ridgebury and Peru Soils

Ridgebury Soil:

General Soil Profile (Inches)	Classification		% Coarse Fragments >3"	% of Material Passing			Permeability Inches per hr.	Available Water Capacity	Soil Reaction (pH)	Shrink Swell Potential
	USDA Texture	AASHO		#4	#10	#200				
0-8	fsl	A-2 A-4	0-15	70-100	65-95	25-65	0.63-6.3	0.06-0.24	4.5-5.5	Low
8-16	fsl	A-2 A-4	0-15	65-95	55-95	20-60	0.63-6.3	0.04-0.20	4.5-5.5	Low
16-40+	fsl	A-2 A-4	5-15	65-95	55-90	20-60	<0.63	0.08-0.10	5.0-6.0	Low

Peru Soil:

General Soil Profile (Inches)	Classification		% Coarse Fragments >3"	% of Material Passing			Permeability Inches per hr.	Available Water Capacity	Soil Reaction (pH)	Shrink Swell Potential
	USDA Texture	AASHO		#4	#10	#200				
0-18	fsl	A-2 A-4	0-10	80-95	70-95	15-65	0.63-2.0	0.10-0.24	5.0-6.5	Low
18-24	fsl	A-2 A-4	0-10	75-95	70-95	30-65	0.63-2.0	0.08-0.21	5.0-6.5	Low
24-40+	fsl	A-2 A-4	5-15	70-95	65-95	20-65	>6.3	0.08-	5.0-	Low

D-12

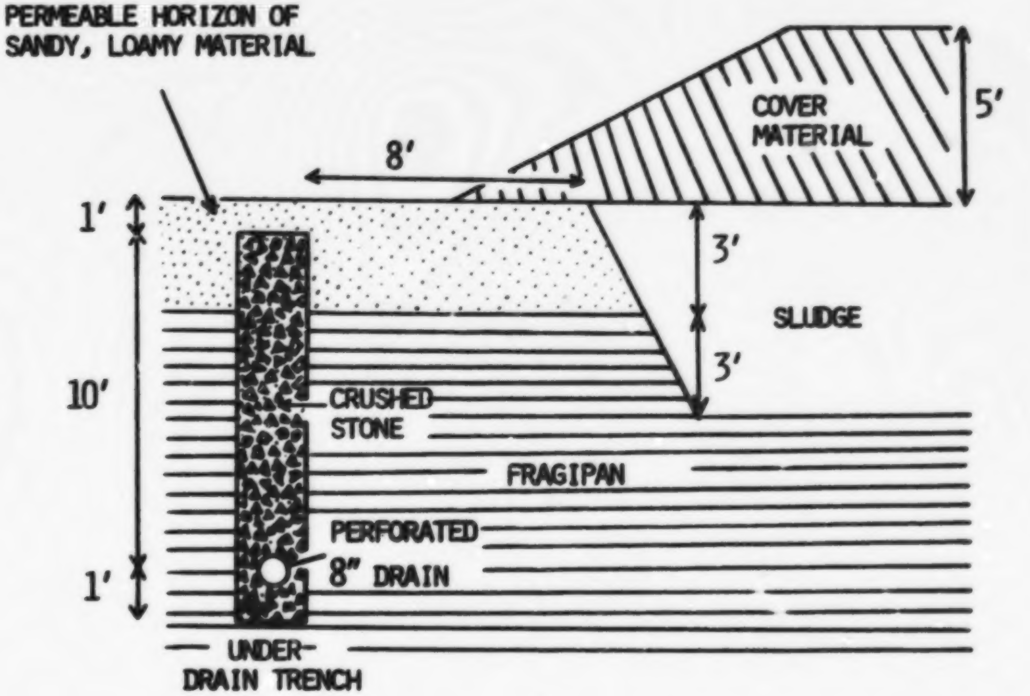

PERMEABLE HORIZON OF SANDY, LOAMY MATERIAL
8'
COVER MATERIAL
5'
1'
3'
SLUDGE
3'
10'
CRUSHED STONE
FRAGIPAN
PERFORATED 8" DRAIN
1'
UNDER-DRAIN TRENCH

Fig. D-6: Cross section showing the relationship of the underdrain trenches to sludge cells and the distribution of soil materials.

A ditch would surround the site to intercept any surface runoff draining from or toward the site. This surface water would also be conveyed to the bottom of the site and allowed to discharge downslope. A 50 ft buffer zone would be left to surround the site.

Within the fill area, parallel pairs of trenches would be installed running perpendicular to the peripheral underdrain trenches and nearly on the land contours. One of these would be dug to a depth of approximately 12 ft and would connect with the peripheral underdrain system. The purpose of this trench would be to ensure that the perched water would be removed and the groundwater table would be lowered sufficiently deep beneath the adjacent ground where sludge would subsequently be deposited. The drainage ditch would be dug sufficiently in advance of any sludge deposition to allow effective draining of the groundwater. The drainage ditch used to lower the groundwater table will be backfilled and a parallel trench for sludge deposition would then be dug. Soil would be excavated each day to accommodate one sludge cell for the amount of waste deposited daily. The dimensions of each sludge cell would be 6' x 8' x 40' for the depth, width and length, respectively (see Fig. D-7). On successive days, sludge cells would be emplaced with their longitudinal axes parallel so that, collectively, these would form a sludge fill zone paralleling the drainage ditch. The sludge cells would have a maximum depth of 6 ft so that the waste would be at least 5 ft above any groundwater table. It was proposed that where the bedrock was nearer than 11 ft to the surface, the sludge layer could be of a reduced thickness in order that 5 ft of fragipan would separate the sludge from the bedrock surface. There was provision in the design for an 8 ft buffer zone of undisturbed soil to be left intervening between the peripheral underdrains and the nearest sludge cells (see Fig. D-6).

During the public hearing to review the PUD application for sludge landfill at Ryerson Hill, it was unclear whether the sludge was of such a consistency that no earth barrier would have to be left between adjacent sludge cells (i.e., the sludge might have a high angle of repose).

D-14

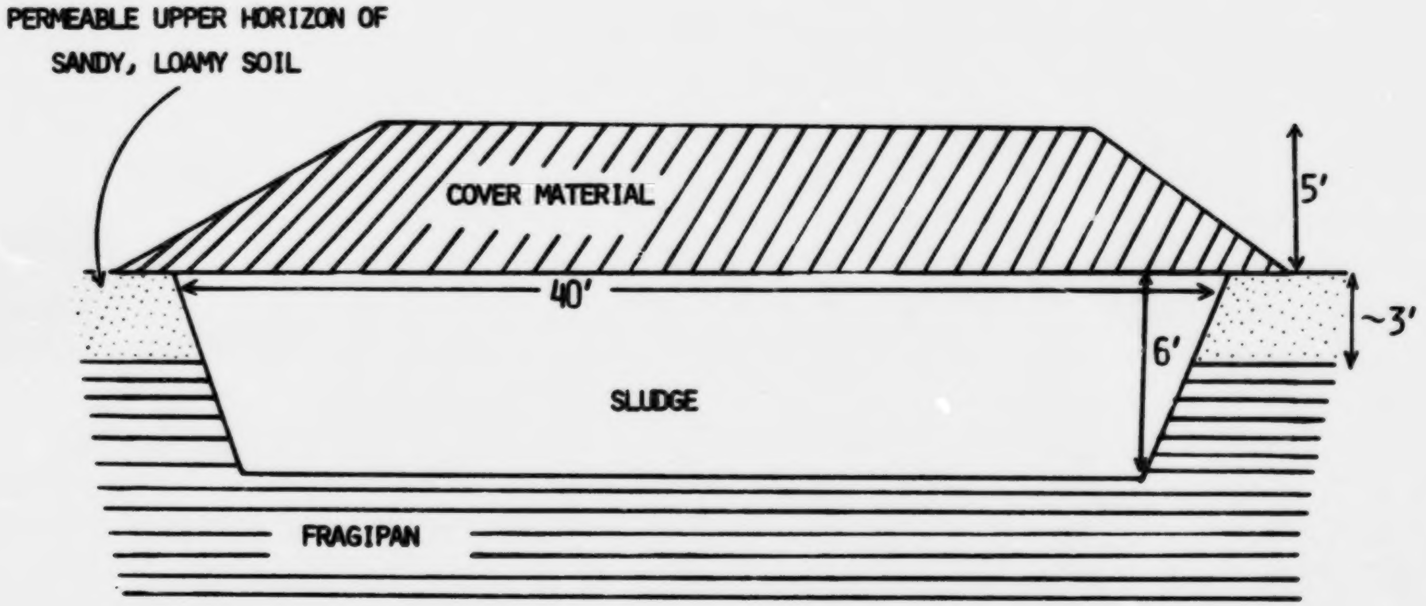

PERMEABLE UPPER HORIZON OF
SANDY, LOAMY SOIL
COVER MATERIAL
5'
40'
6'
~3'
SLUDGE
FRAGIPAN

Fig. D-7: Longitudinal cross section of sludge cell showing distribution of soil materials and cell dimensions.

Observations indicate that the consistency of the sludge is low enough that a soil barrier would be required.

Most of the soil removed from the sludge trenches would be backfilled and graded to produce a 5 ft covering above the sludge. During the initial phase of site utilization (first 10 years), strips of soil would be left unutilized between the parallel sludge-filled areas. During the second phase, trenching and filling would proceed in the intervening parallel zones of soil previously unutilized. Eventually, 80-85% of the site would be utilized. Only that part of the site in the immediate vicinity of current operations would be cleared at any one time. Reforestation and seeding would be carried on as the project progressed.

The Maine Guidelines for Municipal Sewage Treatment Plant Sludge Disposal on Land state that the Ridgebury and Peru soil types which occur at the Ryerson Hill site are unsuitable for the proposed project. This is largely due to the unfavorable natural groundwater situation of these soils. State Regulations for Landfill Site Selection indicate that, although a site may fail to meet certain standard requirements (e.g., percentage of fines, slope, depth to groundwater table), it may be approved, if "through good design and operation it can be shown to provide adequate protection to surface and groundwater resources." The Whitman and Howard design is an attempt to produce an acceptable landfill in accordance with that provision of the State Regulations. The design is a highly innovative one. It should be noted that previous experience with a landfill site of comparable design or of a site where the groundwater table had been lowered prior to site utilization is not available.

Various criticisms of the landfill design were made at the public hearing to review the landfill application. Perhaps the most noteworthy criticism of the design is that although the sludge cells would be in impermeable fragipan at depths greater than about 2-1/2 ft, at shallower depths, the sludge would be within the more permeable upper soil horizon (see Fig. D-7). Although it was suggested that the fragipan could be selectively backfilled by careful excavation procedure, it is questionable whether the disturbed, backfilled fragipan would recover its compact, impermeable characteristics. It was further suggested that vibration compacting could help to restore the fragipan characteristics but this is uncertain. The sludge will probably be contained in cells only partially sealed by impermeable soil. Groundwater incompletely drained from the permeable upper soil horizon could be transmitted with appreciable hydraulic conductivity in the upper, permeable soil in contact with the sludge.

The application had proposed that an 8 ft interval of undisturbed soil would remain between the peripheral underdrain trenches and the nearest sludge cells. In the course of the public hearings, it was suggested that this buffer zone may be insufficient to provide efficient filtering of any leachate and should be much greater than 8 ft. However, the expansion of the buffer zone would reduce the soil area available for sludge deposition. Along these lines, an internal contradiction seems to exist. Whereas the proximity of the underdrain trenches and the parallel drainage trenches to the sludge trenches improves the prospects that groundwater will be drained, it also increases the danger that the leachate will be drained from sludge cells. The groundwater drains may act as conduits for contaminated effluent. Furthermore, since the fragipan is quite impermeable, water could accumulate within the trenches cut into fragipan. This would not move laterally in the fragipan but could "overflow" through the upper permeable soil carrying leachate constituents. The application indicated that the sludge trenches would not conform exactly with the land contours such that a 5% gradient would exist in some trenches. Water accumulating in such trenches could also flow laterally.

Several technical problems regarding the outfall of the underdrain system were noted during the public hearings. It was noted that the 200,000 g/day discharge rate given as a maximum would be highly erosive if not dispersed or impeded before exiting the site. It was recommended by the Androscoggin Valley Regional Planning Commission that a sedimentation basin would be a desirable addition to the design. This would alleviate the erosion problem and provide an opportunity to impound any contaminated effluent (for treatment) if monitoring indicated the escape of leachate components. With the original design, if leachate were detected, there would be no opportunity to deal with the problem and a sedimentation basin might have to be constructed after the fact. Another difficulty with the underdrain discharge is that the outfall might freeze in cold weather. Although the development of a frost penetration layer would prevent any further input to the groundwater system, the underdrain system could cease to remove the groundwater which remained unfrozen. The hydrologic safeguard which the underdrains provide would be lost temporarily and the perched groundwater might encroach in the drained upper soil profile.

The fragipan-spring association applicable to the soils in question has been described in the previous section on local geology. The generation of springs in the site would, obviously, be detrimental to the success of any landfill design. It is difficult, if not impossible, to establish by testing whether springs might be encountered during trench ing. The fragipan could be penetrated by numerous test holes without revealing any artesian source beneath the fragipan. However, the possibility will remain that during excavation of 80-85% of the site, springs will be encountered.

5. Hydrologic Aspects of the Engineering Design for the Ryerson Hill Site

During the course of the hearings concerning the proposed Ryerson Hill landfill, a number of questions were raised regarding the hydrologic aspects of the design. These questions may be considered under two general topics: first, will the design be effective in achieving the stated objectives; second, what, if any, impact will it have on adjacent land.

(a) Hydrologic Aspects of Proposed Design

The proposed design, including subsequent amendments, should be effective in draining initially the perched groundwater table. Interception of groundwater from areas lying uphill (south) of the site by the proposed underdrains, interception of surface runoff by barriers, and drainage provided by parallel ditches to the sludge trenches should remove, at least initially, the perched groundwater table. The major uncertainty in this design lies in the possibility of uncovering a number of springs once the fragipan is excavated. Clearly, special measures will have to be taken if springs are encountered as the fragipan is removed.

Hydrologic events likely at times subsequent to initial draining are difficult to predict. In part, the future hydrologic regime at the site will depend on proper maintenance of the underdrains. Assuming that proper maintenance is provided, a further question to be investigated concerns seepage of water into the sludge trenches with the possible creation of a "bathtub" condition leading to highly concentrated leachate.

It is, at present, difficult to establish whether a perched groundwater table will not be re-established once the drainage ditches are backfilled. If it is assumed that the hydraulic conductivity of backfilled trenches is not substantially different from that of undisturbed soil, use of customary relations for predicting lowering of the groundwater table by the underdrains running along the east and west boundaries of the site shows that they will be insufficient for removing precipitation intercepted by the site.

By way of illustration, consider the usual formula for estimating the extent of lowering of groundwater by either parallel ditches or subsurface drains (Hooghoudt drain-spacing formula)

$$S^2 = \frac{4kH}{\upsilon} (2d + H)$$

where $\underline{S}$ is the distance between drains, $\underline{k}$ the hydraulic conductivity, $\underline{H}$ the steady state (equilibrium) height of the water table above the impermeable layer, $\underline{\upsilon}$ the rate of precipitation, and $\underline{d}$ the height of the drain above the impermeable layer (see, for example, "Drainage Engineering" by J. N. Luthin, John Wiley & Sons, New York, 1966, p. 151). In the present case, $d = 0$ and $k \doteqdot 3 \times 10^{-5}$ fps. If we consider a rate equivalent to the annual rainfall, we would estimate that the drains would have to be spaced about 50 ft apart to insure that on average the precipitation will be drained with no net accumulation of water in the ground. If the backfilled trenches are assumed to have a hydraulic conductivity characteristic of the top soil layers, i.e., of the order of 3×10^{-5} fps, the necessary spacing is still about 200 ft.

The above estimate is obviously only a very rough approximation, but it clearly suggests that water will accumulate, at least seasonally, on the site. Accordingly, some water will almost certainly accumulate within the sludge-filled trenches (since these are partially in the impermeable layer). Given a long residence time, it is probable that leachate which will be generated will be relatively concentrated. Further, local pH values may be distinctly acidic. As noted above, the Peru and Ridgebury soils have pH's of about 4.5 to 6 and the sludge has little buffering capacity. A low pH would be particularly unfortunate given the increased solubility of chromium hydroxide with decreasing pH.

(b) Hydrologic Effects of the Proposed Design on Adjacent Areas

A number of questions were raised at the public hearing in connection with the geometrical pattern and rate of propagation of the drawdown field on adjacent land.

To address the question of the geometry of the drawdown field, the Dupuit equation was used, namely

$$Q = k\frac{H}{L} A$$

with $Q = 0.57$ cfs over length of underdrain, $H = 11$ ft (max), $k \sim 3 \times 10^{-5}$ fps, and $A \sim 11 \times 2300 = 25 \times 10^3$ sq.ft. A solution for L yields about 15 ft as an estimate of the lateral drawdown.

It should be noted that this approach also provides another way of getting an estimate for the drawdown to be expected within the site once the drainage trenches are backfilled. Used in this way, the above formula shows that the lateral drawdown will extend for less than 100 ft.

The Dupuit equation is based on an equilibrium model and, as with other equilibrium models, Q is assumed to be constant across any plane parallel to the drainage ditch. Its use is restricted to a static groundwater table. The equation obviously cannot yield any estimates of the time dependency of the drawdown. Further, the above equation leads to artificial boundary conditions since it predicts that the water table would continue to rise indefinitely with distance from the drainage site (ditch).

In testimony submitted to the board, alternative ways were suggested for modeling the actual impact of the discharge drain and for analyzing the extent of drawdown with time. For example, it was suggested that a solution of the Laplace equation in its polar coordinate form

$$\frac{\partial^2 h}{\partial r^2} + \frac{1}{r}\frac{\partial h}{\partial r} = \frac{S}{T}\frac{\partial h}{\partial t}$$

where S is the storage coefficient and T the transmissibility, would yield a better estimate of the drawdown field. This approach is essentially equivalent to that of the Bureau of Reclamation (see, for example, "Drainage Engineering" by J. N. Luthin, John Wiley & Sons, New York, 1966, p. 165). In general, numerical results from such solutions are not substantially different from those obtained from equilibrium formulas although the description of the shape and extent of the drawdown field is different.

In testimony presented to the board, the time required for the effect of a drainage ditch to be felt at some distance x from the ditch was also estimated. Data were presented which showed that the time required for the water table to reach its "static" level at any distance x from the axis of the ditch were proportional to x^2. Accordingly, the "static" water table is reached rather quickly near the ditch but considerably greater times are required at greater distances. For example, it was suggested that the drawdown field will be established within 100 ft of the drain within one year but that 200 years will be required at 1000 ft.

Testimony was also presented regarding the environmental and ecological effects which might result from changes in local hydrology. For instance, it was suggested that removal of the perched groundwater would convert the area into something akin to a wasteland due to the absence of groundwater. Further, this would increase the potential for erosion presumably because vegetation would not survive. This is doubtful since vegetation is not absent elsewhere in the area where the groundwater table is well beneath any root systems or where geologic circumstances are such that there is no static groundwater. It is more likely that the nature of vegetation will adjust if the permanently saturated soil conditions and shallow water table were removed.

It should be noted that with the shallow layer of permeable soil at this site, the recharge effect of individual storm events are much more consequential in affecting the groundwater table, insofar as any mathematical modeling is concerned, than the precise assumptions of any model. Static groundwater tables calculated in accordance with long-term models are probably unachievable. The general conclusion previously reached, namely that soil recharged by precipitation will not be drained by the proposed ditches at the boundaries, seems proper no matter what specific mathematical model is used. For example, the estimate of the maximum rate of removal of groundwater from the site is of the order of 10^{-3} cfs. The input to the site in a storm event of 1 inch precipitation in 24 hours is about 2 cfs.

6. Summary

The proposed design for the Ryerson Hill site is innovative and unusual, as far as sludge trenching is concerned. Accordingly, operating experience from comparable situations is lacking. In as far as analysis can yield reliable estimates, it appears probable that the site will be effectively drained as proposed. Drainage will be much more difficult if springs are uncovered upon excavation of the fragipan.

The condition of the site after initial drainage is difficult to predict. Even with proper maintenance, it is probable that leachate that may be generated will tend to be concentrated in pollutants. Of particular concern are long contact times of groundwater with buried sludge and the acidic nature of the soils.

If adverse effects appear, they can be contained by impounding leachate and treating it, if necessary. However, such measures imply escalation of costs which are already high. Accordingly, environmental risks can be minimized by proper monitoring and control; the financial risk, however, is substantial.

APPENDIX E

INCINERATION

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APPENDIX E

INCINERATION

1. Background

Incineration is a well known and widely used method of treating municipal and industrial solid wastes. The objectives of incineration can include destruction of noxious materials, recovery of energy from wastes, or reduction of the volume of wastes for final disposal. Frequently incineration achieves a combination of these goals.

Since the composition and volume of wastes to be incinerated varies widely from case to case, most incineration systems are custom-designed for the particular application at hand. While use is made of standard components or subassemblies where possible, the capability of each component to perform satisfactorily in the intended application must be verified. This usually requires testing in vendors' laboratories to establish performance warranties unless the waste material can be reliably classified as "normal", that is, essentially identical to one for which an operating history exists. In this context, municipal refuse or sludge from sewage treatment plants handling only domestic wastes could be called normal.

The components of an incineration system typically include:

- A waste feeding system to introduce the material at a controlled rate to the incinerating device.
- The incinerator proper, in which the wastes are mixed with air and supplemental fuel (if required) and combustion occurs.
- An ash removal system which extracts the solid residues of the combustion process from the incinerator, and
- An offgas treatment system which removes particulates and noxious compounds from the gaseous products of combustion to render the offgases safe for disposal by stacking.

Depending on the circumstances, an incineration system might also include:

- A feed conditioning system to render the waste more suitable for combustion. For example, additional water may be removed from sludge to decrease supplemental fuel requirements, or ferrous metals and large items might be removed from municipal wastes.
- A waste heat recovery or energy production (boiler) system to reduce fuel costs or generate steam, if economically justified.
- An ash treatment system that either recovers valuable scrap from the residues or renders them more suitable for disposal, for example, by simple wetting, agglomeration, or chemical conditioning.

Large incineration systems are typically operated on a three-shift, seven day per week basis, particularly if by-product steam is being produced. Smaller systems may be operated intermittently; for example, one shift per day for five days per week. In either case, more or less continuous operator attention is usually required to insure that all design requirements are being met, even though these systems are typically equipped with automatic instrumentation and controls. Many systems have histories of higher than anticipated maintenance requirements and lower than anticipated production rates due to difficulties in feeding solids at controlled rates, in degradation (corrosion and wear) of refractories and in inadequate performance of offgas scrubbing equipment.

2. Fuel Requirements

Dry wastes containing a high proportion of combustibles or thoroughly de-watered sludges will burn autogenously; that is, once ignited, they require no additional fuel to support combustion. Wet sludges or wastes containing mainly inert material, on the other hand, require a supplemental source of fuel to achieve complete combustion. The exact amount depends on the properties of the waste, combustion temperature, the amount of excess air used, heat losses in the equipment and the presence or absence of waste heat recovery equipment. Estimated supplemental fuel requirements for combustion of sludge from the South Paris facility are shown in Figure E-1 as a function of sludge solids content for systems with and without waste heat recovery. A typical (800°C) combustion temperature has been assumed with 25 percent excess air and with nominal system heat losses for the combustion of 14,000 lb/d (dry weight basis) of sludge containing 35% non-combustibles, the balance having a heating value of 9000 BTU/lb. No. 2 fuel oil is the assumed supplemental fuel. Clearly an energy recovery system would pay if the current low solids sludges were to be incinerated, but the total supplemental fuel requirements would be substantial even if plant design sludge solids contents (20%) were achieved. While supplemental fuels other than No. 2 fuel oil might be considered, their use would present other problems. Natural gas, for instance, is unlikely to be available. Admixing combustible municipal refuse would require approximately 1/6 lb of dry refuse (heating value 5000 BTU/lb) per pound of (wet) sludge, assuming use of an energy recovery system. Not only would this complicate the incineration system's material handling section, but it also would require an extensive and costly refuse collection system. Alternatively, approximately 1/5 lb of green sawmill wastes per lb of (wet) sludge might be used, if available locally. Collection of sawmill wastes might be simpler than municipal refuse collection, but the same materials handling problems would arise.

3. South Paris Sludge Incineration System

An incineration system for sludge produced in the South Paris treatment plant is shown schematically in Figure E-2. It has been assumed that if relatively low percent solids sludge continues to be produced, a subsequent solids treatment step will be employed to remove more water so as to save fuel. The supplemental fuel will be No. 2 fuel oil.

Sludge from the existing plant would be fed, at a controlled rate, to the solids treatment step to effect further water removal. It has been presumed that thermal treatment, using energy obtained from the

E-4

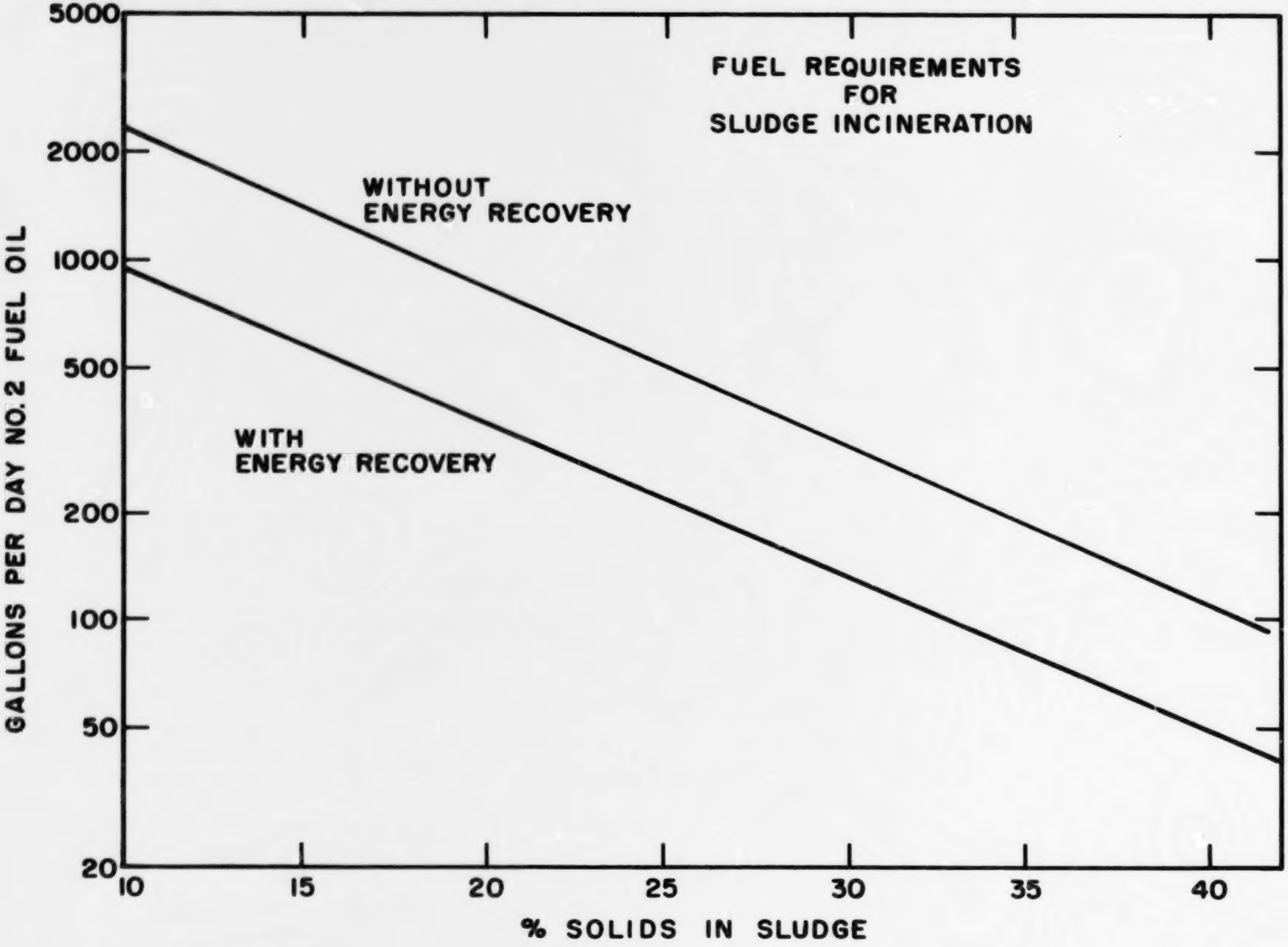

Fig. E-1: Fuel requirements for sludge incineration as a function of percent solids in sludge.

COMPONENTS OF A SLUDGE INCINERATION SYSTEM

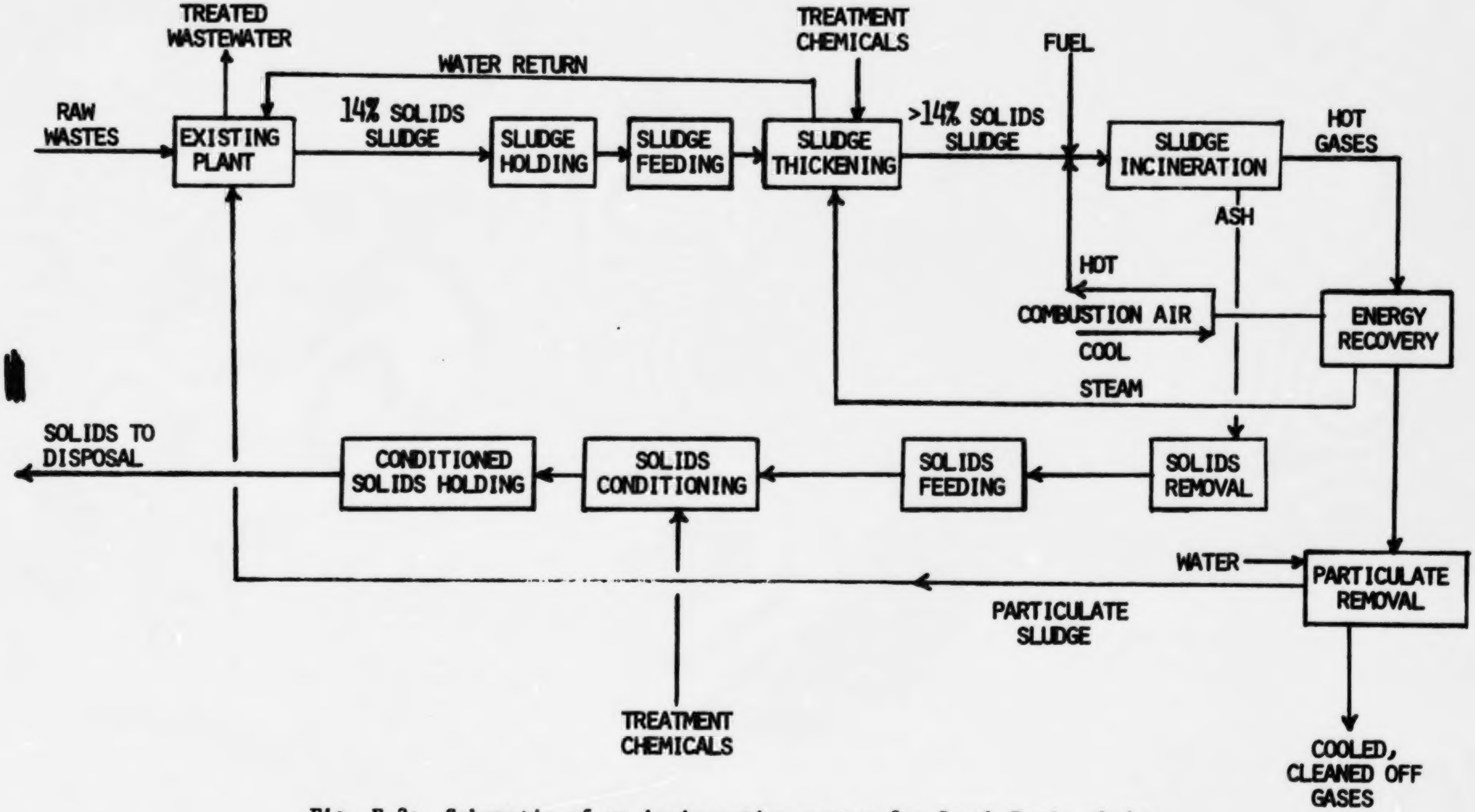
TREATED WASTEWATER
WATER RETURN
TREATMENT CHEMICALS
FUEL
RAW WASTES
EXISTING PLANT
14% SOLIDS SLUDGE
SLUDGE HOLDING
SLUDGE FEEDING
SLUDGE THICKENING
>14% SOLIDS SLUDGE
SLUDGE INCINERATION
HOT GASES
ASH
HOT
COMBUSTION AIR
COOL
ENERGY RECOVERY
STEAM
SOLIDS TO DISPOSAL
CONDITIONED SOLIDS HOLDING
SOLIDS CONDITIONING
SOLIDS FEEDING
SOLIDS REMOVAL
WATER
PARTICULATE REMOVAL
PARTICULATE SLUDGE
TREATMENT CHEMICALS
COOLED, CLEANED OFF GASES

Fig. E-2: Schematic of an incineration system for South Paris sludge.

combustion step, followed by a thickening step, will be effective in upgrading the sludge solids content to about 20%. Such an efficiency has been demonstrated on some sludges, but must be considered uncertain for this sludge until actually demonstrated in pilot testing. The additional water removed from the sludge in this step would be returned to the treatment plant and the sludge held in surge for feeding to the incinerator proper.

The sludge would be fed to the incinerator at a controlled rate along with sufficient fuel and air to achieve complete combustion. Several styles of incinerators, including fluidized beds, traveling grates, multiple hearths, or rotary kiln types, might be used. Fluidized bed units, however, are generally used for much larger volume applications than contemplated here. Traveling grate types find application mainly in refuse combustion and are also used primarily on higher throughput applications. Multiple hearth and rotary kiln units do extend to the range of capacities anticipated here. Cost estimates were obtained for a "packaged" standard rotary kiln incinerator, which would probably have the lowest total installed costs in this application. The package includes an automatic ash removal system to transfer residues to a subsequent conditioning step and an offgas scrubbing system.

The products of combustion, hot gases containing particulates, would pass to an energy recovery system. Here they would be cooled, giving up sensible heat to the inlet combustion air, thereby reducing supplemental fuel requirements. The offgases would next be quench-cooled and scrubbed with water to remove particulates and sludge components that were volatilized but not combusted in the incinerator. The combustion gases, cleaned after passage through the scrubber, would be stacked, while the sludges from the scrubber would be recycled to the incinerator via the treatment plant.

Several types of scrubbers might be considered, including venturis, spray towers, or cyclonic spray scrubbers. These devices differ in cost and scrubbing efficiency, and the determination of the most appropriate type would normally be made during combustion tests in the incinerator vendor's pilot plant. From these tests, the extent and composition of particulates would be determined and scrubber design requirements specified.

It is to be expected, based on previous incineration of mixtures of chrome and calcium, aluminum and sodium compounds, that under normal incineration conditions, the chrome contents of the sludge would be oxidized to the toxic and soluble Cr(VI) state. While combustion at very high temperatures or in oxygen deficient (substoichiometric) conditions might reduce chromium oxidation, the former would require very expensive equipment and much more fuel than for normal combustion and the latter has not been demonstrated to be effective in this application. In any case, neither approach is likely to be completely effective in preventing the formation of Cr(VI). The ash, therefore, must be treated further to permit safe final disposal.

The most appropriate treatment appears to be admixture, after rewetting, of suitable chemical additives. The additives are mixed with the ash at a controlled rate and chemical reactions initiated that cause the additives to "set up", thereby immobilizing the ash constituents in an inert, insoluble matrix. Several types of chemical systems are in commercial applications and one, using silicate-based chemicals, has been used on chrome plating bath sludges which are similar in some respects to the South Paris sludge. As is the case with incineration proper and offgas scrubbing, pilot testing would be required to determine accurately both the costs and effectiveness of this technique.

In summary, a sludge incineration system for South Paris would include an additional sludge dewatering step, an incinerator, energy recovery, and offgas scrubbing system, and a chemical ash conditioner system. It would require significant amounts of supplemental fuel of some type (oil, sawmill waste, refuse) and would require continuous operator attention to function properly. While high capital and operating costs would be incurred, such a system should greatly decrease the volume of solids to be disposed, probably by a factor of two or so depending on the chemical conditioning system used. The reduced volume and more favorable properties of the dried and conditioned incinerator wastes would significantly increase the life of any final disposal area and could mitigate the risk of accidental ground water contamination.

In Paris, however, the amount of sludge produced per capita is about five times higher than is normal for purely domestic waste treatment facilities, the sludge contains (at present) 50-100% more water per pound of dry solids than normal, and the solids contain far more toxic heavy metals (chrome) than is usually found in domestic sludges. These features inevitably imply unusual design and operating problems for an incineration system.

4. Capital and Operating Costs

Estimates of the capital and operating costs for sludge incineration and conditioning were made to determine if these techniques could be cost effective in South Paris. Since no tests have been carried out on the sludge, the configuration proposed for the incineration system is preliminary and costs estimates carry uncertainties of ± 50%. The vendor testing and engineering design efforts required to develop process operating specifications and definitive cost estimates would entail approximately a $50,000 expenditure if a relatively simple system is contemplated.

The capital cost estimate for the system is detailed in Table E-1. A vendor quote was solicited on the incinerator proper, based on combusting 20% solids sludge, and is a firm price, subject only to escalation. The uncertainty in the total installed cost of $600,000 is about ± 25%. If the sludge could not be thickened beyond 14% solids, the cost of the incinerator and total installed costs, would increase by some $200,000.

A vendor estimate was also obtained on the costs of silicate-based chemical conditioning systems to immobilize the chrome contents of the sludge or the combustion ash. Such a system is required for rendering the ash safe for disposal, but might also be considered as an alternative to incineration for treating the current wet sludge. The costs for a

Table E-1

Capital Cost Estimate for a Sludge Incineration System

System Component	Estimated Cost (thousands)	Source of Estimate[1]
Sludge Holding & Feeding	20	E.E.
Sludge Thickening	50	E.E.
Sludge Incineration Particulate Removal Solids Removal	300	V.Q.
Energy Recovery	20	E.E.
Solids Feeding Conditioning Holding	60	V.E.
Total Purchased Equipment Costs	450	
Site Preparation, Installation, Instrumentation, Support Facilities, etc.	150	V.E.,E.E.
Total Installed Cost	$600	

---

(1) V.Q. = Vendor Quote
V.E. = Vendor Estimate
E.E. = EIC Estimate

system to condition the daily production of a 14% solids sludge are summarized in Table E-2. In the absence of test data, the vendor estimate of the cost of the conditioning system proper, which is at the higher end of the manufacturer's capabilities, is accurate to within ± 25%.

While this cost is significantly less than that for an incineration system, conditioning wet sludge in this manner would not decrease the volume and, therefore, would not significantly increase the life of the disposal area. Any increase possible would be derived from a more efficient management of the site made possible by the improved mechanical properties of the conditioned solids.

Operating costs estimated for both incineration and conditioning of the sludge are summarized in Table E-3. Utility costs include power and water, and maintenance costs include only necessary materials and supplies. Estimated maintenance labor requirements have been included with operating labor; about two man-years of total labor would be required for either option. The fuel cost estimate for incineration presumes that a 20% solids sludge can be produced; combustion of a 14% solids sludge would double the fuel requirement. Fuel costs include start-up and stand-by fuel requirements. Materials and supplies costs include the silicate-based conditioning chemicals required in this application, and are in the high range of those suggested by the conditioning system vendor. While this comparison indicates that incineration entails lower operating costs, this assumes a sludge containing 20% solids can be produced, a condition which as yet has not been demonstrated. Furthermore, under favorable conditions, the conditioning chemicals' costs might be almost halved: If this could be demonstrated in pilot testing, disposal of wet, conditioned sludge could become a much more cost competitive alternative.

Table E-2

Capital Cost Estimate for a Sludge Conditioning System

System Component	Estimated Cost (thousands)	Source of Estimate[1]
Sludge Holding & Feeding	20	E.E
Sludge Conditioning Holding Chemical Feeding	130	V.E.
Total Purchased Equipment Costs	150	
Site Preparation, Installation, Instrumentation, Support Facilities, etc.	50	E.E.
Total Installed Cost	$200	

---

(1) V.E. = Vendor Estimate
E.E. = EIC Estimate

Table E-3

Operating Cost Estimates
Sludge Treatment Systems

(thousands of dollars per year)

	Incineration and Conditioning	Conditioning Only
Materials & Supplies	15	130
Utilities	15	10
Fuel	60(1)	-
Maintenance(2)	15	5
Operating Labor	15	15
Total Direct Operating Cost	$120	$160

---

(1) 20% solids feed to combustion.

(2) 2.5% of total capital cost.

APPENDIX F

TREATMENT PLANT EFFLUENT AND WATER QUALITY OF LITTLE ANDROSCOGGIN RIVER

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APPENDIX F

TREATMENT PLANT EFFLUENT AND WATER QUALITY OF LITTLE ANDROSCOGGIN RIVER

1. Water Quality

Treatment plant operations and their impact on water quality of the Little Androscoggin River were not, strictly speaking, part of this work. However, it was desirable to assess waste loads introduced directly into the river by treatment plant effluent in order to make a judgment about the relative impact of pollutants that may reach the river in the form of leachate from the A. C. Lawrence landfill site.

Data obtained by the treatment plant showed an improving trend (June-August 1976). This improvement has hopefully continued. DEP data on water quality show that Little Androscoggin water is of good quality above South Paris but that a significant drop in water quality is found downstream of South Paris.

2. Treatment Plant Effluent

A series of analyses of treatment plant effluent was carried out on 10/26/76, 10/27/76 and 10/28/76. Part of each effluent sample collected at the plant was filtered and tested for hexavalent chromium on site. The filtrate was acidified and analyzed later for dissolved metals. Another part of the sample was not filtered and was used for determination of COD. Whole, unfiltered samples were also digested with acid and used for determination of total (dissolved and suspended) chromium content. Results of the analyses are shown in Table F-1 and are plotted as a function of time in Figs. F-1 through F-6.

Although the treatment plan operations have improved over the first year of operations, the plant periodically experiences bulking. When this condition occurs, secondary sludge is wasted directly into the effluent. The results given in the table and figures were obtained when

Table F-1

South Paris Plant Effluent
(Concentrations in mg/liter)

		Chromium			Sodium	Calcium		
Date	Time	Dissolved	Total	Cr(VI)	Total	Dissolved	Total	COD
10/26	8:00	0.15	-	-	-	132	-	-
	9:30	0.14	-	-	-	130	-	-
	10:45	0.13	34.6	nd	650	96	148	1110
	11:45	0.28	42.2	nd	670	114	157	1500
	12:20	0.18	14.2	nd	640	121	130	732
	13:15	0.18	-	nd	640	106	-	-
	14:10	0.18	66.4	nd	708	78	159	2810
	15:10	-	54.4	nd	740	-	156	1450
	16:10	-	12.6	nd	824	-	150	717
	17:05	-	2.8	nd	656	-	129	299
	18:05	-	4.0	nd	786	-	141	243
	19:05	-	3.2	nd	818	-	143	210
	20:10	-	8.2	nd	836	-	148	374
10/27	8:00	-	2.8	nd	840	-	141	208
	9:10	-	3.4	nd	846	-	149	327
	10:30	0.20	40.0	nd	820	102	166	1390
	11:15	-	82.2	nd	842	-	180	2630
	12:10	-	73.6	nd	850	-	173	2480
	13:10	0.20	85.4	nd	886	144	178	1810
	14:10	-	94.4	nd	829	-	176	2810
	15:15	0.23	44.8	nd	912	143	170	1320
	16:10	-	31.8	nd	900	-	167	965
	17:00	0.20	14.2	nd	920	142	161	600
	18:10	-	13.2	-	860	-	153	252
10/28	8:05	-	2.2	-	810	-	157	175
	9:10	0.18	10.0	nd	850	161	169	300
	10:25	0.20	54.6	nd	830	144	176	1700
	11:05	-	110.4	nd	880	-	196	2870
	12:00	-	89.6	-	860	-	181	2210
	13:00	-	18.6	-	890	-	151	844

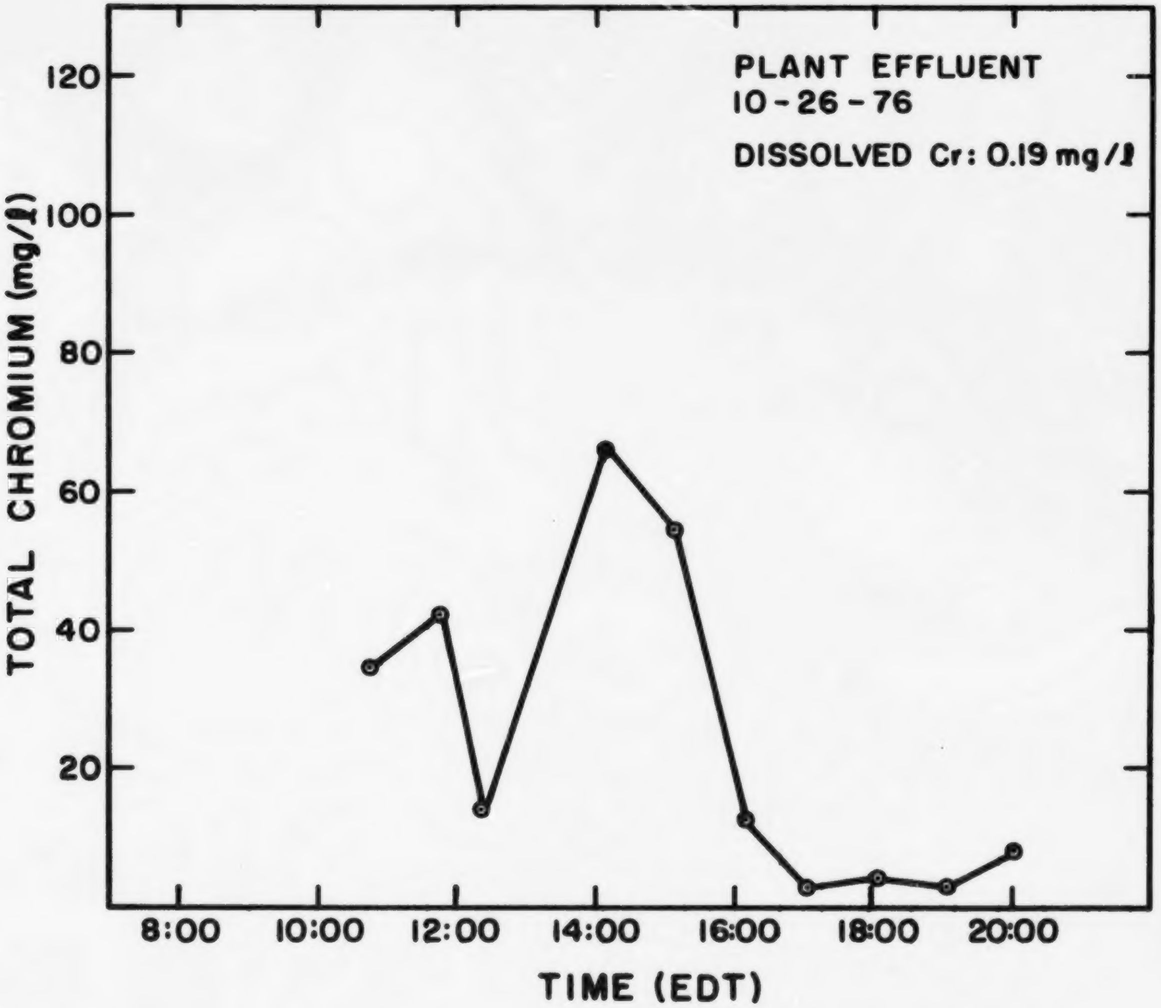

Fig. F-1: Chromium concentrations in plant effluent, 10/26/76.

F4

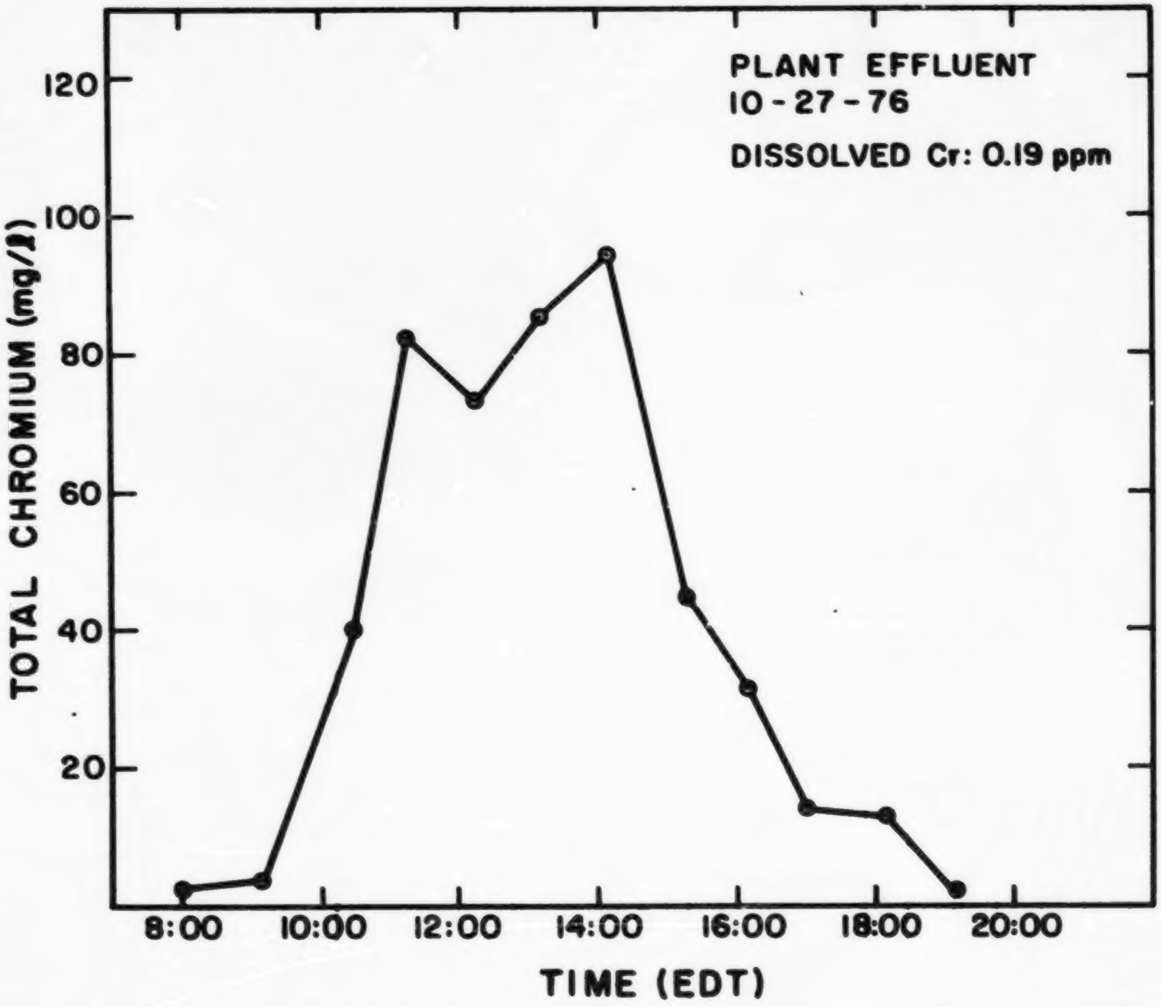

Fig. F-2: Chromium concentrations in plant effluent, 10/27/76.

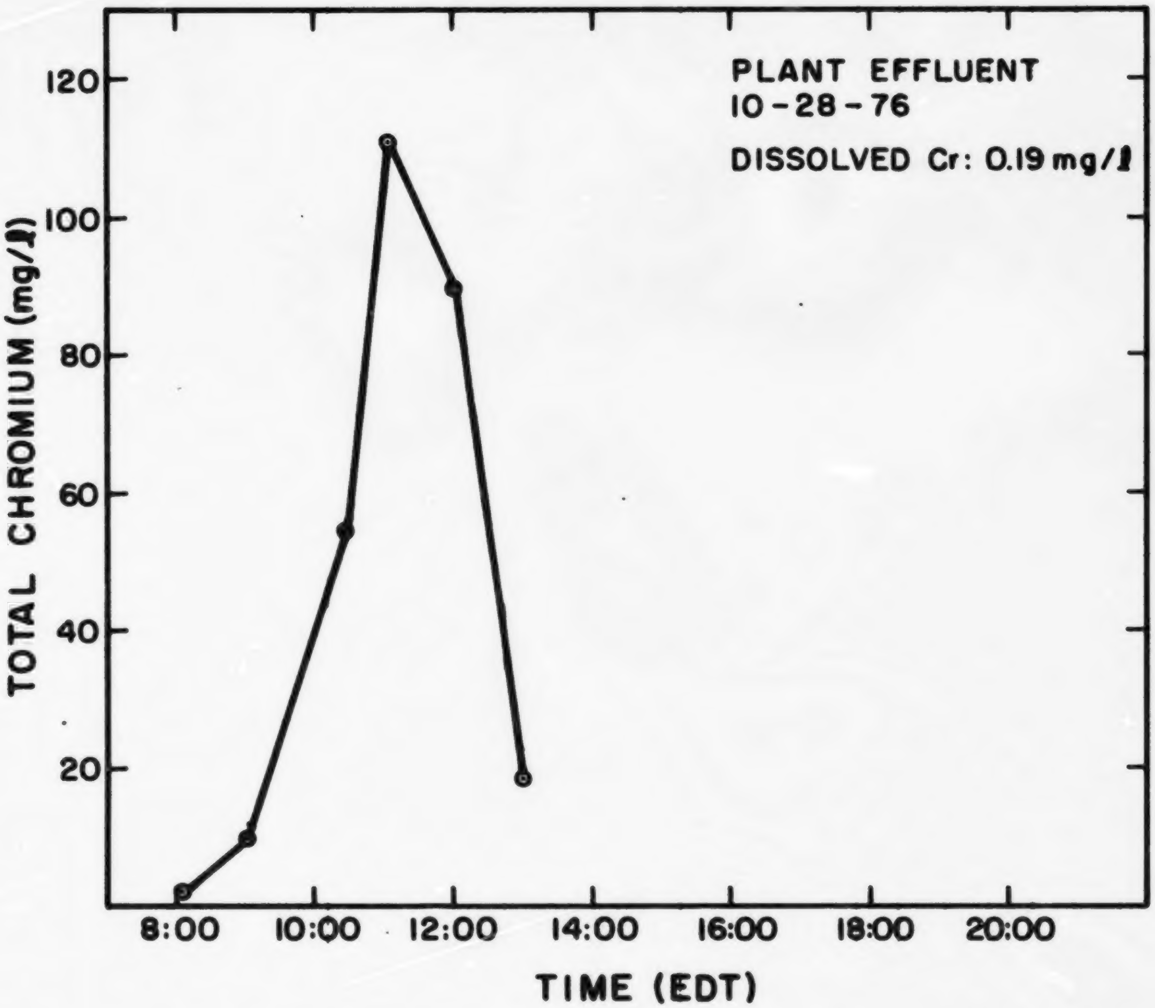

Fig. F-3: Chromium concentrations in plant effluent, 10/28/76.

F6

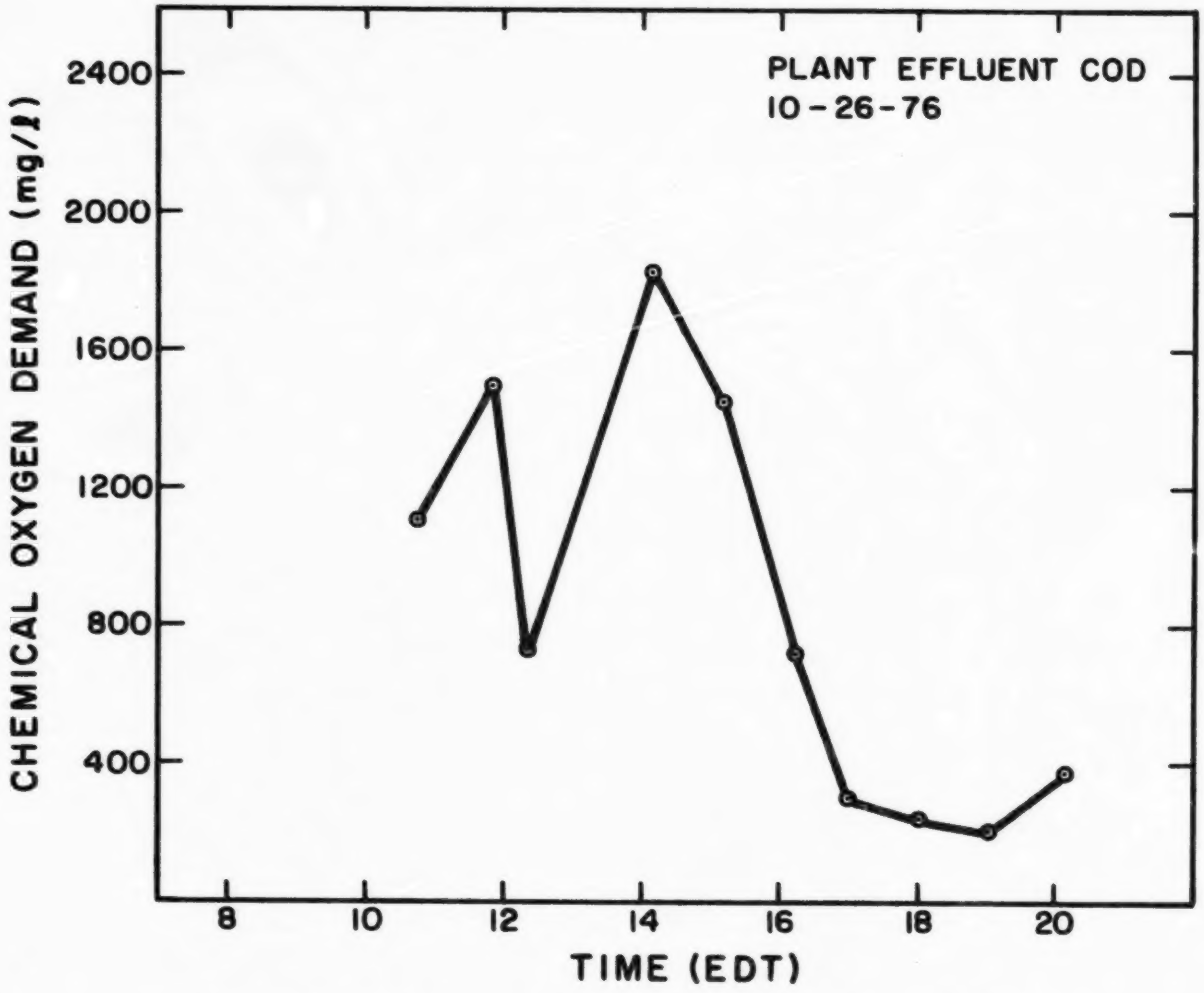

Fig. F-4: Chemical oxygen demand of plant effluent, 10/26/76.

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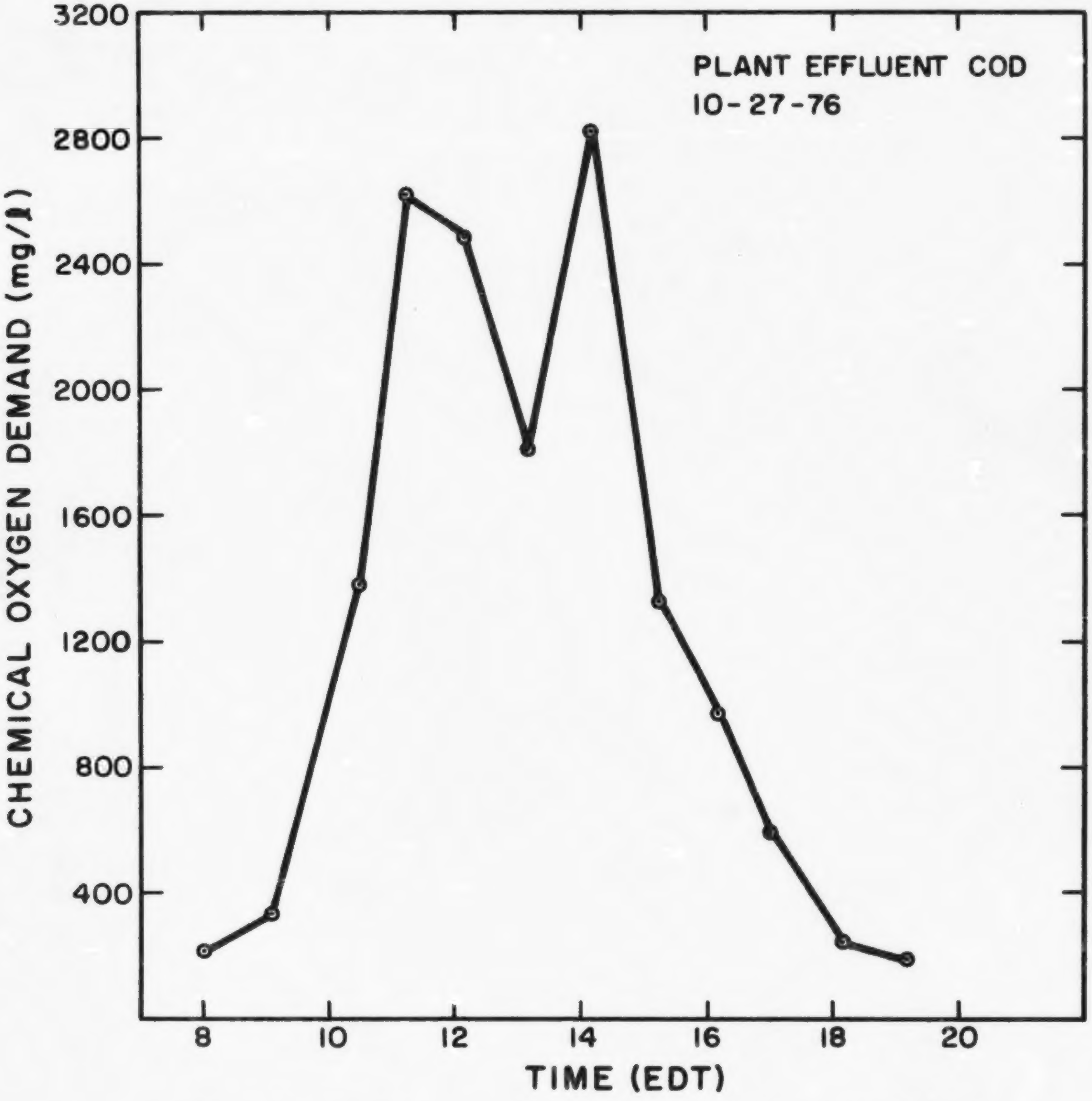

Fig. F-5: Chemical oxygen demand of plant effluent, 10/27/76.

F8

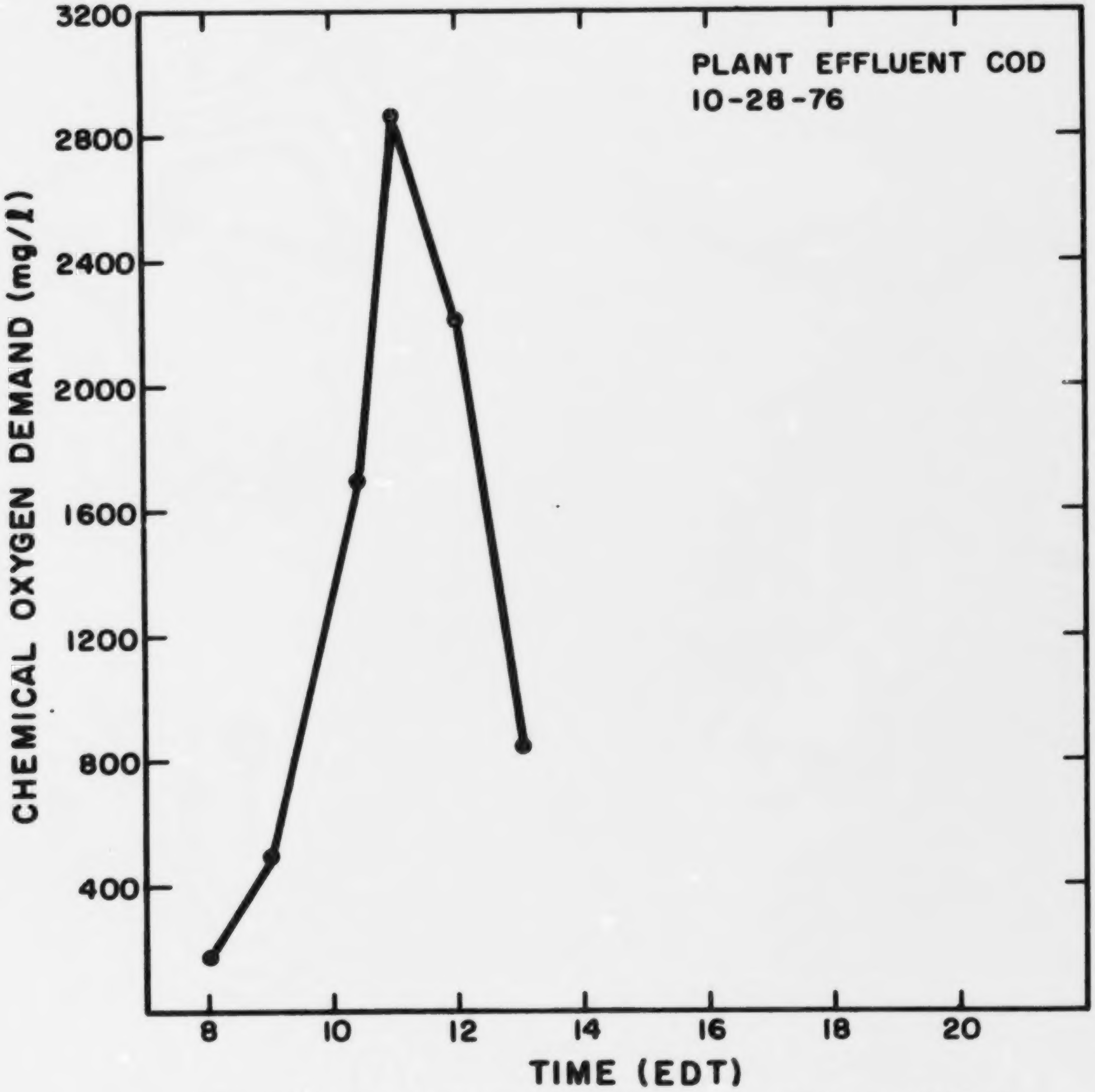

Fig. F-6: Chemical oxygen demand of plant effluent, 10/28/76.

the plant was bulking. As can be seen from these data, bulking leads to drastic deterioration of effluent quality, with peak discharges of chromium up to 100 ppm. It should be noted, however, that even under such conditions, chromium is discharged as particulates. The amount of dissolved chromium, i.e., chromium determined after filtration through a 0.45 micron filter, is only a small fraction of the total (approximately 0.2 ppm out of a total of 50-100 ppm). The calculated equilibrium solubility of chromium hydroxide in effluent (at pH = 7.0 to 7.3, see Table F-2) is in the range of 0.3 ppm to 0.1 ppm. The amount of dissolved chromium found in effluent (0.15 to 0.20 ppm) is in good agreement with what is expected from the solubility of chromium hydroxide. It is clear, therefore, that there are no significant contributions to dissolved chromium from other forms of chromium, for example, organically complexed chromium (see Appendix B).

The origin of the bulking problem at the wastewater plant is complex. An analysis of influents to the plant and of streams within the plant was carried out in November of 1976 (11/18/76 and 11/19/76). The results, given in Table F-2, show that beamhouse and tanhouse waste streams from the A. C. Lawrence tannery fluctuate substantially in Cr content and pH. Such fluctuations in input streams may affect operations of the plant.

3. Analysis of River Water

A series of water samples were collected about 1 river mile downstream from the wastewater plant, approximately at a point in the river near the Norway dump. These samples were filtered, the filtrate acidified, and both particulates and filtrate later analyzed for chromium. Results are given in Figs. F-7 through F-9.

It is clear from the figures that chromium content in the river shows fluctuations corresponding to the fluctuations of input from the plant. The dilution at the point of observation was about 1:300. It may be noted that on the three days of observations (10/26/76, 10/27/76, and 10/28/76), the Little Androscoggin River mean daily discharge at

Table F-2

Chromium Concentration and pH in Wastewater Treatment Plant Streams

	Beam House Influent		Tan House Influent		Upflow Effluent		Plant Effluent	
	pH	Total Cr (ppm)	pH	Total Cr (ppm)	pH	Total Cr (ppm)	pH	Total Cr (ppm)
11/18/76								
10:00	12:35	18.6	4.75	135.0	9.25	17.5	7.38	2.64
12:00	9.60	7.72	4.35	33.7	9.21	16.6	7.40	7.73
14:00	11:22	104.0	3.62	568.0	9.45	22.0	7.38	11.5
16:00	9.38	6.84	9.65	28.6	9.30	26.6	7.25	8.44
18:00	9.32	4.10	9.42	4.12	9.38	28.8	7.30	3.00
11/19/76								
10:00	12.12	56.2	3.50	1235.0	9.20	19.8	7.05	21.2
11:00	-	-	3.88	218.0	-	-	-	-
12:00	9.13	85.0	6.51	325.0	9.00	22.5	7.13	34.2
13:00	-	-	6.03	49.8	-	-	-	-
14:00	9.75	10.2	7.20	32.9	9.05	8.60	7.05	19.6
15:00	-	-	9.90	9.10	-	-	-	-
16:00	9.91	1.96	9.62	2.84	9.17	6.90	7.00	17.8
17:00	-	-	9.40	12.2	-	-	-	-
18:00	8.50	0.78	9.85	6.82	9.19	5.06	7.02	8.10

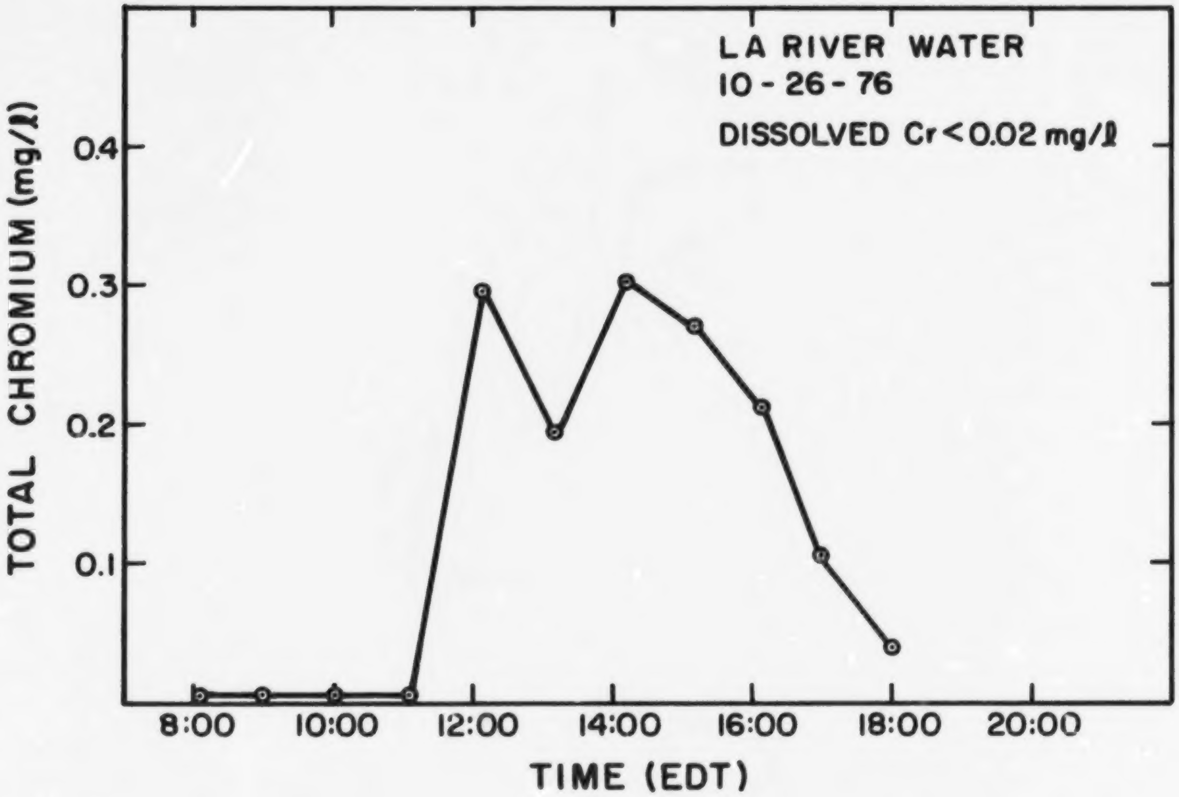

Fig. F-7: Total chromium suspended in river water, 10/26/76.

F11

F12

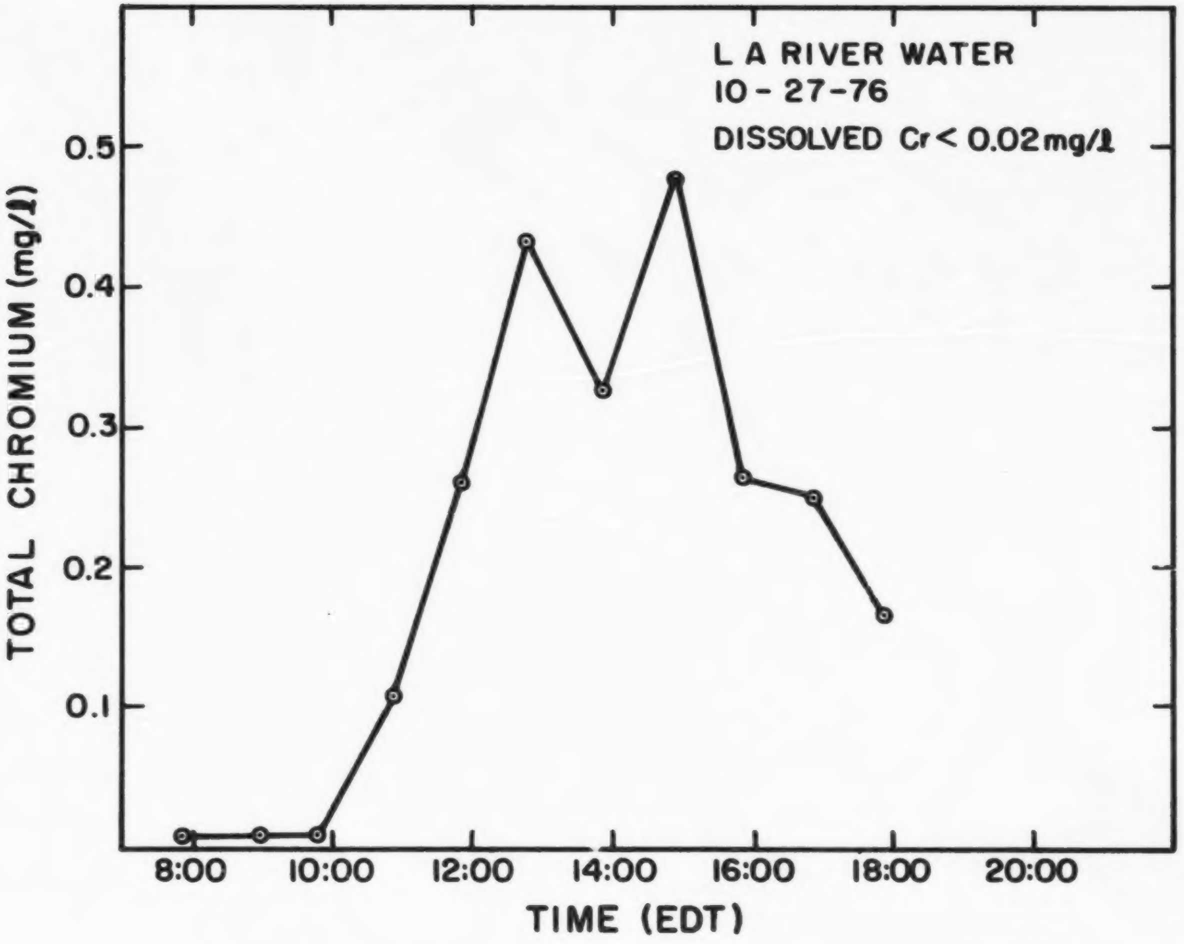

Fig. F-8: Total chromium suspended in river water, 10/27/76.

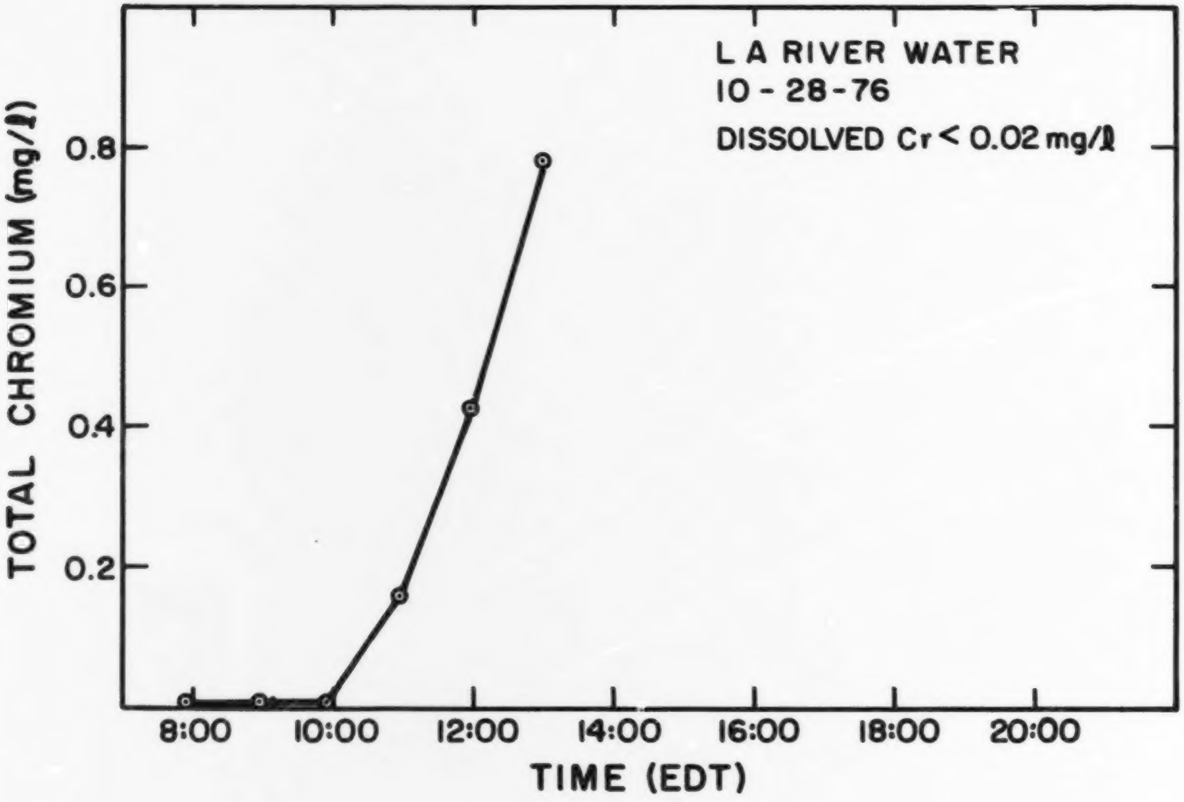

Fig. F-9: Total chromium suspended in river water, 10/28/76.

South Paris was 245, 215, and 180 cfs. The average rate of discharge by the plant was about 4 cfs over about 8-10 hrs. The expected dilution is, therefore, about 1:50 as compared with an observed dilution of about 1:300. Accordingly, a substantial amount of particulate Cr must settle between the point at which plant effluent is discharged into the river and the observation point (Norway dump).

Sediments removed near the bank of the Little Androscoggin River at the Norway dump were analyzed for chromium. About 2000-3000 ppm of Cr were found. Sediments removed from the middle of the river (where the bottom is more or less continuously scoured) showed essentially no chromium (a few ppm).

It may be noted that river water is quite low in dissolved chromium (less than 0.02 ppm). The amount of dissolved chromium is, in fact, well within the limit for chromium in drinking water (0.05 ppm).

4. Additional Sampling of Treatment Plant Effluent

Additional sampling for chromium of treatment plant effluent was carried out on 11/18/76, 11/19/76 and on 2/22/77. On 11/18/76 and 11/19/76, the plant was bulking and total chromium levels were in the 10 to 30 ppm range. Dissolved chromium was 0.21 ppm.

Results for 2/22/77 are given in Table F-3. The plant was operating normally. It is clear from the table, that under normal (non-bulking) conditions, the amount of total chromium in the effluent is quite small (1-2 ppm). Dissolved chromium is about the same, viz. about 0.2 ppm, whether the plant is bulking or not.

Table F-3

Treatment Plant Effluent of 2/22/77

Time of Sample	Total Cr (ppm)	Dissolved Cr (ppm)	Calcium (ppm)	Sodium (ppm)
9:30 am	1.50	0.15	427	170
11:30 am	1.47	0.17	302	168
1:30 pm	2.45	0.32	352	204
3:30 pm	2.19	0.32	292	183
5:30 pm	2.47	0.22	329	180

APPENDIX G

ARCHAEOLOGICAL EXAMINATION OF LAWRENCE AND RYERSON HILL SITES

UNIVERSITY OF MAINE at Orono

Department of Anthropology
Maine Archaeological
Conservation Program

Stevens Hall, South
Orono, Maine 04473
207/581-7102, 7122

May 23, 1977

Dr. Frank T. Rabe
EIC Corporation
55 Chapel Street
Newton, Mass. 02158

Dear Dr. Rabe:

At your request I examined proposed sludge disposal areas in Paris, Maine on May 20, 1977.

Because of the proximity of the river to the Lawrence site it seemed to be a prime area for an archaeological site. I examined the area on foot and then tested with a series of shovel test pits. The nature of the soil leads me to suspect that recent soil accumulation has been limited. Accordingly, I restricted my testing to roughly 30 cm deep holes. I tested first along the northern end of the dumping area and then in the new proposed area to the south. The results of my tests were negative. It is my opinion that nothing of historical significance will be disturbed by further sludge disposal at the proposed Lawrence site.

I drove to the location of the Ryerson Hill site , but as I suggested in my letter of April 14 the area has practically no potential for anything of historical significance. Test pits did not appear to be warranted.

I hope that this informal report will give you the necessary information. Thank you for asking for my services on this job. As an archaeologist it is always a little disappointing when a site does not turn up, but negative evidence is also useful.

Yours sincerely,

David Sanger

David Sanger
Director